IOT AND CLOUD COMPUTING SOLUTIONS FOR NEXT-GENERATION AGRICULTURE AND ANIMAL HUSBANDRY

G. Abbas[1*], S. Jaffery[2], M. Arshad[1], A. Mustafa[1], A. H. Hashmi[6], M. Iqbal[19], M. Kamal[7], M. A. Naveed[1], M. Abduljabbar[1], M. A. Khan[1], M. Abbas[13], U. Farooq[15], M. F. Khalid[15], Z. Ahmad[9], M. S. Imran[12], K. Imran[14], M. Auon[15], H. Farah[3], R. A. Qureshi[11], M. A. Gondal[10], M. Imran[16], K. Parveen[4], M. Abbas[17], M. N. Butt[6], S. A. Abbas[6], A. Raza[5], H. Abbas[18], M. Jamshaid[1], Z. Abdullah[6], A. A. Khan[6], W. Sohail[1], A. Khalid[8]

[1]Riphah College of Veterinary Sciences, Riphah International University Lahore, Pakistan
[2]Faculty of Agriculture, University of Agriculture Faisalabad, Pakistan
[3]Department of Sports Sciences and Physical Education, University of Lahore, Pakistan
[5]Department of English Language and Literature, University of Lahore, Pakistan
[6]University Institute of Food Science and Technology, University of Lahore, Pakistan
[7]Department of Mass Communication, Government College University, Faisalabad, Punjab, Pakistan.
[8] The University Institute of Diet and Nutritional Sciences, University of Lahore, Pakistan
[9] School of Systems and Technology, University of Management and Technology, Lahore
[10]Cholistan University of Veterinary and Animal Sciences, Bahawalpur, Pakistan
[11]Department of Physics, Riphah International University Lahore, Pakistan
[12]Department of Pathology University of Veterinary and Animal Sciences, Lahore, Pakistan
[13]Inner Mongolia Saikexing Institute of Breeding and Reproductive Biotechnology in Domestic Animal, Hohhot, Inner Mongolia, China
[14]Department of Food Science and Human Nutrition, University of Veterinary and Animal Sciences, Lahore, Pakistan
[15]University of Agriculture Faisalabad, Sub campus Toba Tek Singh, Pakistan
[16]Pet Centre, University of Veterinary and Animal Sciences, Lahore.
[17]PetsWorld Animal Hospital, Faisal Town Lahore
[18]Department of Computer Science, Virtual University, Pakistan.
[19] Department Industrial and Manufacturing Engineer, University of Engineering & Technology, Lahore
.[*]**Corresponding Authors:** ghulamabbas_hashmi@yahoo.com

ABSTRACT: The significance of the internet of things (IoT) has grown considerably due to the expanding user base apprehensive computing and universal applications. It includes a wide range of devices, from simple objects to sophisticated sensor nodes, which can be used to deliver multirange services. Cloud computing and IoT offer life-changing potential for animal husbandry and agriculture by improving sustainability, efficiency, and productivity. The vast amount of data generated by IoT necessitates cloud computing, as standalone systems may struggle to manage it effectively. IoT with the cloud, known as the Cloud of Things (CoT), proves instrumental in achieving the optimal objectives reliant on IoT. In animal sciences, integrating the CoT may help in a transformative era for animal care, monitoring, and research. With the utilization of IoT devices and sensors, veterinarians and researchers can gather real-time data on various aspects of animal health, behavior, and environmental conditions. The cloud-based infrastructure of CoT enables the storage and analysis of vast datasets, allowing for comprehensive perceptions of animal well-being, early disease detection, and behavior patterns, which not only enhance the efficiency of veterinary care but also opens new vistas for research in understanding and addressing the complex health dynamics of diverse species. The use of CoT/IoT in animal sciences may help to provide complete data-driven solutions for meeting the rising global demand for food and other agricultural products by improving the growth, welfare, and health of animals. However, addressing challenges like infrastructure, data security, and costs will help to fully understand the benefits.

Keywords: IoTs; Cloud computing; CoT; smart gateway; fogging; animal science, farm management

(Received 15.04.2024 Accepted 01.06.2024)

INTRODUCTION

The future of computing depends on the combination of the IoT and cloud computing, ushering in a new era of fully automated digital technology. IoT is not merely a concept or buzzword; significant progress is underway, making it an integral part of our daily lives. As we progress into the next-generation internet, leveraging IoT becomes crucial. Integrating IoT with the cloud is essential for harnessing and processing vast amounts of data. With the proliferation of connected devices, it's expected that soon the number of these devices will exceed the human population connected to the internet. Recent years have seen a remarkable flow in internet traffic, where the data generated by just 20 households now exceeds the entire internet usage in 2008.

Currently, the IoT has emerged as a cornerstone technology, gaining significant adhesion across various sectors of life owing to its ability to facilitate context-aware computing and general applications. The principle of IoT lies in its vast ecosystem of devices, ranging from simple objects to sophisticated sensor nodes, all interconnected to deliver innumerable services. However, the exponential growth in IoT adoption has led to a record swell in data generation, requiring robust computational infrastructure for effective management. This is where cloud computing steps in, offering a scalable and flexible solution to handle the massive influx of data. By integrating IoT with cloud computing, often referred to as the CoT, organizations can unlock the full potential of IoT, leveraging its capabilities to achieve optimal objectives and outcomes.

In the realm of animal sciences, the integration of CoT represents a transformative approach to animal care, monitoring health, and research. Through the utilization of IoT devices and sensors, veterinarians and researchers can access real-time data on various aspects of animal health, behavior, and environmental conditions. This real-time monitoring capability enables practical involvement and management strategies, ensuring the well-being of animals in diverse settings [137]. Moreover, the cloud-based infrastructure of CoT serves as a centralized hub for the storage and analysis of vast datasets, offering a complete understanding of animal health and production.

The utilization of CoT in animal sciences not only enhances the efficiency of veterinary care but also opens new opportunities for research and innovation. By connecting the power of data analytics and machine learning algorithms, researchers can gain deeper insights into complex health dynamics and disease patterns among different species. Early disease detection becomes feasible through predictive modeling and anomaly detection techniques, enabling timely intervention and mitigation strategies. Furthermore, the analysis of behavior patterns within animal populations can shed light on environmental stressors and habitat preferences, informing conservation efforts and ecosystem management practices [123].

In short, the use of CoT in animal sciences represents a paradigm shift towards general, data-driven solutions aimed at improving the welfare and well-being of animals [139]. By understanding the health and behavior patterns in greater depth, stakeholders in the animal husbandry field can plan more effective management strategies and interventions, ultimately fostering a symbiotic relationship between humans and animals in the present-day interconnected world.

Background

A. IoT: The IoT represents a pivotal technological advancement, extending the connectivity of millions of devices to the Internet for data exchange. IoT's influence spans across various domains, integrating sensors (see table 1) into diverse environments [151; 152; 153]. This interconnectedness signifies an important shift in computing, surpassing traditional hardware and software integration to include social interaction [2]. IoT's impact is evident in automation [155] such as self-driving cars [3], healthcare [4], home automation [5], energy [6], and agriculture [7] sectors. For instance, IoT facilitates data-driven decision-making and machine-to-machine communication in self-driving cars, healthcare monitoring, and precision agriculture. The architecture of IoT typically comprises layers such as Perception, Network, and Application, with some models including additional layers like Middleware and Business [1, 8; 120; 119].

The IoT architecture consists of multiple layers, starting with the Perception layer, which collects data from the environment using sensors, RFID (radio frequency identification) tags, cameras, and GPS [9]. The Network layer transports this data to the Internet via gateways or processing centers. The Middleware layer manages services, stores data, and makes automatic decisions before passing data to the Application layer. Here, data is processed and presented in various applications such as smart transportation, smart home, and intelligent agriculture [154]. The Business layer focuses on modeling works and services to generate revenue, utilizing the processed data and services offered by the Application layer [8]. These layers work together to collect, process, and present data, ultimately creating value and potential revenue sources for service providers, as described in Figure 1.

IoT revolutionizes industries by enhancing safety, efficiency, and monitoring capabilities across various production sectors [10; 132]. In aerospace and aviation, it identifies counterfeit goods, reducing accidents from unauthorized parts [11]. Automotive applications include smart sensors for tire pressure and proximity detection, alongside RFID streamlining manufacturing. Telecommunications integrates IoT for innovative services, while healthcare benefits from remote monitoring and prompt intervention through RFID-equipped mobile devices. In pharmaceuticals, IoT tracks medications, ensuring compliance with regulations, particularly for products requiring specific storage conditions. Environmentally, IoT aids conservation by efficiently managing resources through wireless identifiers. Generally, IoT's adaptability underscores its potential impact on safety, healthcare, manufacturing, and environmental monitoring.

A. IoT and the Food Industry: The IoT has numerous applications in the food industry, revolutionizing various processes from production to distribution to consumption. IoT sensors can monitor various parameters such as temperature, humidity, pH levels, and more in real-time. This ensures that food products remain fresh and safe throughout the supply chain, reducing spoilage and wastage [137]. Maintaining the integrity of the cold chain is critical for perishable food items [138; 139]. IoT sensors can monitor temperature variations in refrigerated trucks, warehouses, and storage facilities, ensuring that products are stored at optimal conditions from farm to fork [138].

Table 1 The IoT, demonstrating its key aspects and applications.

Aspect	Examples	Description	References
Definition	Smart home devices, wearable health monitors	Network of interconnected devices (things) that communicate/exchange data over the internet.	232; 233
Applications	Smart lighting, remote patient monitoring, precision farming	Numerous domains such as smart cities, healthcare, manufacturing, and agriculture.	234; 235
Components	Temperature sensors, motion detectors, RFID tags	Sensors, actuators, connectivity, data processing, and applications.	234
Technologies	MQTT, LoRaWAN, AWS IoT, Azure IoT Hub	Wireless protocols (Bluetooth, Wi-Fi, Zigbee), cloud computing, edge computing.	234; 235
Challenges	Data breaches, regulatory compliance	Security, privacy concerns, data management, interoperability, and scalability.	235
Examples	Nest Thermostat, Fitbit, John Deere Precision Ag	Smart Home including HVAC control, and light controller. Healthcare includes remote patient monitoring. Agriculture includes soil moisture sensors. Industry Predictive maintenance.	232; 234; 235

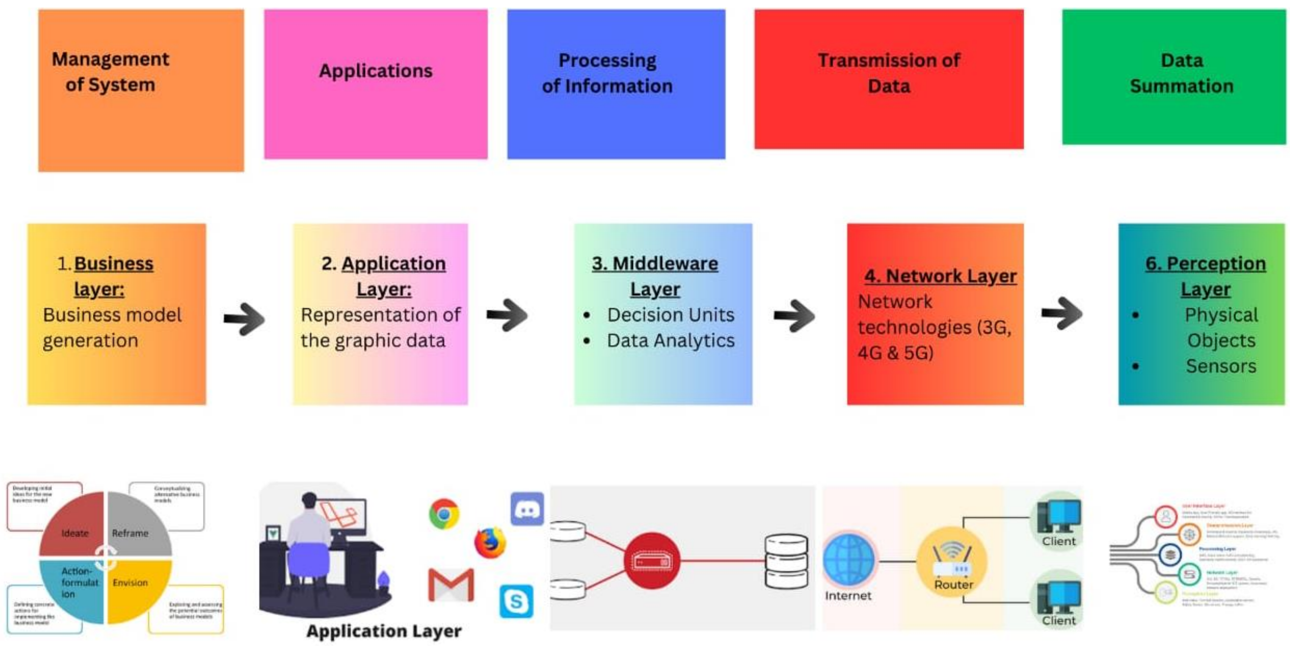


Figure 1. IoT or Programmable Object Interfaces Layers

IoT-enabled inventory systems can track stock levels in real-time. This helps in optimizing supply chain operations, reducing overstocking or stockouts, and minimizing wastage due to expired or spoiled products. Blockchain technology integrated with IoT devices can enable end-to-end traceability of food products. Consumers can access detailed information about the origin, production process, and journey of the food they purchase, ensuring transparency and authenticity [139a].

Smart packaging equipped with IoT sensors can provide information about the freshness and quality of food products. These sensors can detect factors such as gas composition inside packaging, indicating the freshness of perishable items. IoT devices such as soil sensors, drones, and smart irrigation systems enable precision agriculture practices. Farmers can monitor crop health, soil moisture levels, and environmental conditions in real-time, leading to optimized resource usage and increased yields [140].

IoT-enabled vending machines and retail stores can offer personalized recommendations based on customer preferences and purchasing behavior. These systems can also monitor inventory levels, automate replenishment processes, and enhance the overall shopping experience. The technology can assist in compliance with food safety regulations by automating data collection, monitoring critical control points, and providing real-time alerts in case of deviations from safety standards [140].

Interpreting data collected from IoT sensors, food companies can gain insights into consumer behavior, market trends, and demand patterns. This facilitates better production planning, inventory management, and distribution strategies [141]. IoT-enabled kitchen appliances can assist consumers in meal preparation, recipe suggestions, and grocery shopping. These devices can also track food consumption patterns and provide nutritional understanding to promote healthier eating habits [142].

These applications demonstrate how IoT technology is transforming the food industry by improving efficiency, safety, and sustainability across the entire supply chain.

B. Transforming Poultry Farming: A Sustainable Approach with IoT-Based Environmental Management: Chicken is widely recognized as a popular and nutritious source of protein [114], often considered healthier than red meat [143; 112; 152]. The economic feasibility of raising chickens for meat production, coupled with the increasing global demand, has resulted in substantial growth in the chicken industry [153; 162].

Nutritional Benefits and Versatility: Chicken is valued for its high-quality protein, low cholesterol, and minimal saturated fat, making it a preferred ingredient in diverse culinary settings, including restaurants, hotels, fast-food establishments, and social events [154]. The adaptability of chicken in various recipes contributes to its widespread popularity and profitability within the poultry industry.

Poultry Farming Methods: Chicken meat primarily comes from two farming methods: open type poultry shed (traditional farms) and controlled-shed poultry farms (modern farms). Controlled-shed poultry farms are recognized for their higher efficiency and productivity compared to conventional farms [155].

Environmental Impact on Chicken Health: The production of chicken meat is closely linked to environmental factors such as the chick's growth environment, rearing duration, and farm care practices [155]. Inadequate care in farmhouses can lead to chicken health issues, including respiratory, digestive, and behavioral problems, especially in controlled sheds. Broiler chicks are found to be more sensitive than breeder chicks [156].

Environmental Parameters and Challenges: Maintaining specific environmental parameters, including temperature, relative humidity, oxygen levels, carbon dioxide concentration, ammonia gas levels, and carbon monoxide levels, is vital for poultry health [126; 134; 135; 136; 157]. Mismanagement of these factors can result in increased costs, bio-security risks, and hindered business growth.

Digital Technologies in Poultry Farming: There is a growing interest in leveraging digital technologies for sustainable poultry farms [158]. The manual operation of environmental components in poultry farms can lead to suboptimal outcomes, including compromised food quality, increased expenses, and hindered business expansion. Digital innovations, such as smart farming, have the potential to improve efficiency, economic returns, environmental sustainability, and working conditions in the field [159].

Population Growth and Sustainable Resource Use: The global demand for food, particularly chicken meat, has risen with rapid population growth. Ensuring sustainable use of natural resources, including water and food, has become imperative. Digital innovation in agriculture, as highlighted by the United Nations Food and Agriculture Organization, holds promise for reducing poverty, hunger, and mitigating climate change consequences [121; 160; 161].

Scholars have widely investigated concerns related to the environment of poultry houses [162] and probed into technological advancements in poultry farming aimed at boosting productivity and mitigating greenhouse gas emissions, specifically focusing on smart poultry management systems [122; 160; 161] underscored the direct influence of environmental conditions on poultry well-being and productivity, while Tjao *et al*. (2019) emphasized the importance of maintaining optimal temperature levels for different age groups of chickens. Veeralakshmi *et al*. [164] reported ammonia as a significant environmental pollutant produced from chicken farming, impacting both the ecosystem and bird health. Researchers such as Thamba et al. [166] and Natraj et al. [166] highlighted the need for monitoring factors like light exposure and egg quality in controlled sheds. Moreover, recent studies by Vijayan et al. [167] proposed intelligent algorithms like ECCO (Error Correction Chaos Optimization) to enhance energy efficiency and minimize the Age of Information in Industrial IIoT systems, illustrating the dynamic evolution of digital solutions in poultry farming [127]. Collectively, these studies emphasize the interdisciplinary nature of poultry farming, tackling challenges through technological innovation and comprehensive environmental management.

The Poultry Environment Monitoring System (PEMS) incorporates a range of software tools into its integrated software and hardware framework. Eclipse, a widely used integrated development environment (IDE), is employed for the creation and management of PEMS's software components [128; 168]. MySQL, a robust relational database management system, serves as the foundation for data storage and retrieval in PEMS, efficiently handling structured data using SQL. Complementing MySQL, MySQL Workbench provides a graphical tool for database schema design and administration **[20; 129; 129a]**. WildFly, a modular and lightweight application server, functions as the runtime environment for PEMS's web-based application, ensuring seamless communication with the underlying hardware. The Java Development Kit

(JDK) is an important toolkit for the development of PEMS's software, facilitating the creation of core functionality by the Java language programming. PEMS is deployed (as a dynamic web-based application) on Amazon Web Services (AWS) and offers secure user access via a URL. Authorized users can observe environmental and auto conditions, tracking data trends, and making informed decisions to improve poultry health conditions and production across diverse range of farm houses [157]. The integration of WildFly, MySQL Workbench, Eclipse, MySQL, and JDK constitutes the technological foundation that allows PEMS to offer real-time insights and actionable data for real poultry farm management.

Building upon the identified limitations and opportunities, future research and development can explore several avenues. Firstly, extending the study to include multiple poultry farms would offer a wide-ranging understanding of varying challenges across different farm settings. Analyzing data from several farms could lead to the identification of best practices and guidelines for ideal environmental and management conditions **[21]**.

Secondly, the integration of data analytics and machine learning techniques **[22]** could improve the proficiencies of IoT-based sensor systems. For this, advanced algorithms could sense patterns, guess potential deviations, and recommend practical interventions to maintain ideal environment conditions.

Moreover, the integration of automated actuators sensor systems with control mechanisms could allow real-time modifications based on sensor analyses **[23]**. This would create a more intelligent and self-regulating farm environment, reducing the reliance on manual interventions and optimizing resource utilization [118].

Additionally, the utilization of energy harvesting techniques **[24]** for the longevity of IoT nodes may also be recommended. These future research directions aim to enhance the efficiency, intelligence, and sustainability of poultry farming practices.

The provided information discusses the implementation of an IoT system in a poultry farm to monitor and control various environmental parameters crucial for the well-being and growth of chicks. Let's segregate the poultry-related data along with the respective references:

Temperature Monitoring (SHT20 Sensor): The temperature range remained within standards, but it dropped below 30 °C in the last 2 days.

Alerts are sent if the temperature falls below 30 °C, prompting corrective actions. **[08]**

Relative Humidity Monitoring (SHT20 Humidity Sensor): Alerts are generated if RH falls below a predefined threshold for timely corrective actions.**[08]**

Oxygen Concentration Monitoring (Grove O2 Sensor): Higher oxygen concentration contributes to a favorable environment for chick growth.

SMS alerts are triggered if oxygen levels fall below a critical threshold of 16% **[25].**

Carbon Dioxide Monitoring (MQ-135 Sensor): The system generates SMS alerts if CO2 levels exceed 500 ppm threshold for timely corrective measures.**[26]**

Carbon Monoxide Monitoring (Winson ZEO7-CO Sensor): Continuous monitoring ensures timely detection of variations, with SMS alerts triggered if CO levels surpass 500 ppm.**[27]**

Ammonia Gas Monitoring (Winson-ME3NH3 Sensor): An automatic alert system sends high-priority notifications to the supervisor and medical personnel if ammonia levels exceed 80 ppm.**[14; 124]**

A. **An Environment of Cloud Computing:** Cloud computing has significantly alleviated concerns regarding resource management and maintenance for users. Recent trends in information technology indicate that cloud computing can shift computing processes from individual desktops to the World Wide Web (WWW). Under this model, users are responsible for covering the expenses through a Pay-as-you-use system. Devices such as smartphones can serve as interfaces to data centers in cloud computing. Presently, most devices rely on cloud computing for data processing, making it a fundamental component of modern computing. Cloud computing plays a crucial role in our lives by enabling us to store data, including memories and documents, on the cloud for universal access, with minimal risk of loss due to its backup features. Its utility extends across various fields, including marketing analysis [12], E-government [13], industry [14] Healthcare [15], and E-education [16]. In the marketing realm, past data stored in the cloud is leveraged to inform future decisions and drive product promotion strategies. Government services such as online degree verification, visa applications, and FIR systems rely solely on cloud computing infrastructure for their operation. Industries utilize cloud computing to consolidate data from various units into central repositories, facilitating supply chain management and product development efforts. Patient data is securely stored in centralized cloud platforms, enabling efficient diagnosis and ongoing monitoring of individuals with similar medical conditions. The advent of cloud computing has been instrumental in enabling online education, particularly significant during the COVID-19 era. E-learning, enabled by centralized data processing and advanced resources, has proven more effective than traditional learning methods. Cloud computing represents a comprehensive integration of parallel computing, grid computing, and distributed computing paradigms [17;18;19;20;21; 130;131].

Cloud computing simplifies access to data centers without the need for cumbersome computing and storage devices. It also facilitates the sharing of extensive media content. With its rapid advancement, cloud computing has become the latest cutting-edge technology. Offering highly manageable, schedulable, and scalable virtual servers, storage, network bandwidth, computing power, and virtual networks, cloud computing caters to users' affordability and specific requirements. Media management is a crucial aspect of cloud computing, particularly concerning the sharing and organization of vast amounts of digital media. Cloud computing provides a manageable and convenient solution for container handling across various distributed environments, allowing for seamless access from devices to high-grade servers without the hassle of managing large storage devices.

Hence, it is crucial to delve into the significance of intelligent communication rooted in Fog computing and smart gateways, which form the cornerstone of smart communication. This involves the convergence of IoT with Cloud computing, commonly referred to as the CoT. Additionally, it is essential to explore performance evaluation through machine learning techniques, facilitated by centralized data processing and state-of-the-art resources.

When discussing the global computing network, it's evident that the count of connected devices has surpassed the world's population since 2011. The tally of connected devices has already exceeded 9 billion and is projected to soar to approximately 24 billion by the conclusion of 2020 [19]. As the number of connected devices continues to rise, there is an anticipated surge in the volume of data generated [22]. Storage of data locally temporarily can pose challenges, highlighting the need for renting storage space to ensure the utilization of this stored data is worthwhile. Mere data processing to generate information is insufficient; rather, this information must be transformed into intelligence for users. Achieving this requires additional processing, which is not feasible at the IoT end due to the lightweight and cost-effective nature of the devices. Cloud computing emerges as the optimal solution for this processing on a rental basis. The convergence of cloud computing and IoT in such a manner gives rise to a novel model known as the CoT [23; 24].

The CoT aids IoT in resource management and offers more efficient and cost-effective methods for service delivery. Through CoT, an expanded and innovative array of services is made available. CoT facilitates seamless and universal access to services for users, thereby broadening the scope of offerings. Consequently, service providers stand to gain increased revenue. Additionally, CoT enables robust analysis of data generated by IoT, enhancing the effectiveness of time-sensitive and emergency-related IoT data interpretation.

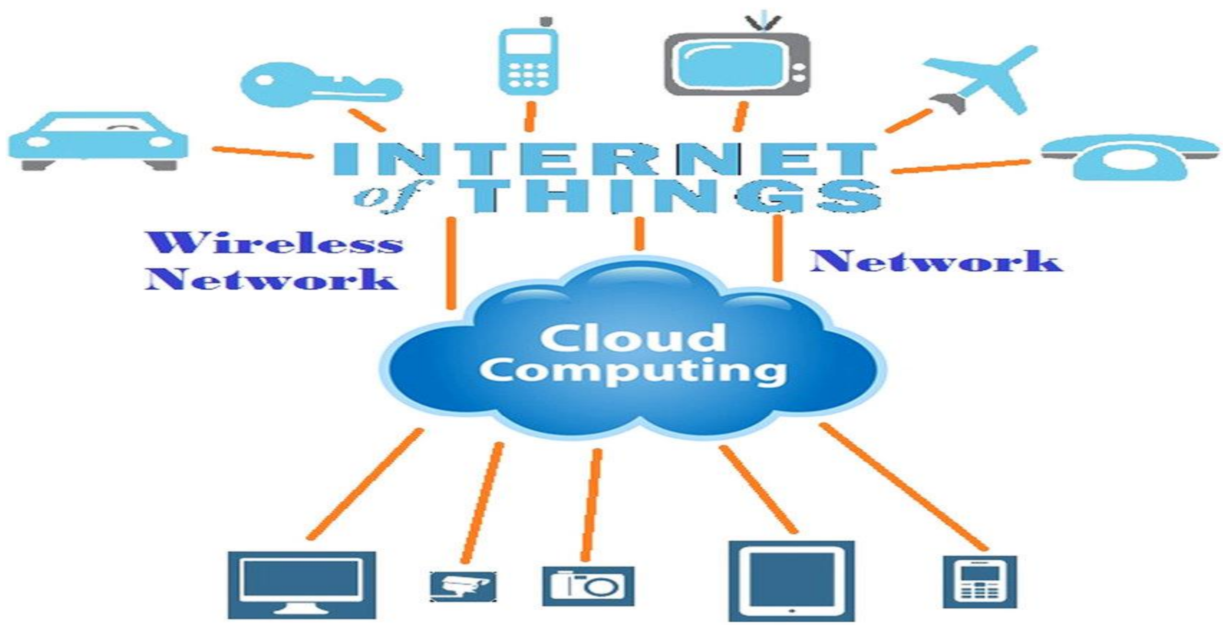


Figure 2. CoT

B. SYSTEM ANALYSIS:

1. **3.1: EXISTING SYSTEM:** Traditional poultry farming systems are primarily manual, complex, and

costly, with inaccuracies in measuring temperature and humidity, posing risks to chicken health and the coop atmosphere. These systems, often non-user-friendly and environmentally unfriendly, depend heavily on manual labor and face challenges like high maintenance costs and power outages.

2. **3.2: PROPOSED SYSTEM:** In contrast, the proposed "Poultry Pal" system employs IoT technology to create a more secure, predator-proof coop without traditional latches. It utilizes sensors for monitoring temperature, humidity, and water levels, enhancing chicken safety and health. Data monitoring and notifications are managed through the MYMQTT application, with data storage in the ThingSpeak cloud application, offering a more efficient and automated poultry management solution.

C. **4. HARDWARE USED:** Node MCU, Servo Motor, Water level Sensor, DHT11, Piezo Electronic Buzzer, PIR Sensor, IR sensor, LED, Connecting Wires.

5. SOFTWARE USED:

- Arduino IDEVersion1.8.13
- Operating System Windows 7 and above (64bits)

6. LIST OF MODULES

1. Coop Open and close using an Infrared sensor
2. Detecting the presence of chicken in the coop with a passive infrared sensor.
3. DHT11 detects the range of temperature and humidity
4. The water level depth sensor identifies the level of water in the coop

1. **Coop Open and close using Infrared sensor:** The coop utilizes an IR sensor to detect chickens, automatically opening and closing the door upon detection. This sensor, emitting light in the infrared spectrum, can measure object heat and motion. The system comprises an infrared source, transmission medium, optical components, detectors, and signal processing, using infrared lasers and LEDs for effective operation.

Figure 3- IR SENSOR (*Infrared (IR) Sensor Module with Arduino – A blog about DIY solar and arduino projects (solarduino.com)***)**

2. Detecting the presence of chicken in the coop with a passive infrared sensor:
PIR sensors, used for motion detection, are efficient and durable. They operate by detecting infrared radiation levels, with a design that splits the sensor to identify motion changes, not
average IR levels.

Figure 4-PIR SENSOR (Adafruit's Profile - Instructables)

3. DHT11 detects the range of temperature and humidity: The DHT11 sensor, available as both a sensor and module, measures temperature and humidity. It uses a thermistor and capacitive humidity sensor, offering a temperature range of 0-50°C and humidity range of 20-80%, with a 1Hz sampling rate for accurate, real-time data.

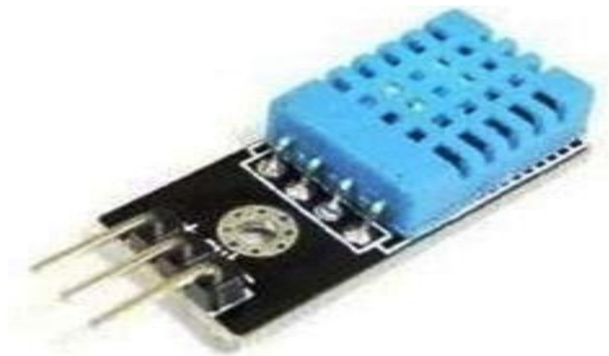


Figure 5- DHT11 (DHT11 Sensor Pinout, Features, Equivalents & Datasheet (components101.com))

4. The water level depth sensor identifies the level of water in the coop:
The water level depth sensor in the chicken coop monitors water availability, alerting users via mobile notification. It's a low-cost, probe-type sensor, effective for various materials, and requires calibration for specific substances and tank designs.

Figure 6- WATERLEVEL SENSOR
SYSTEM ARCHITECTURE (Water Level Depth Sensor Module – QuartzComponents

Blockchain and CoT: Bitcoin, which was created in 2008 by a person going by the name Satoshi Nakamoto, is most commonly recognized for its use of blockchain technology [25].

In recent times, researchers have shown growing interest in blockchain technology, recognizing its potential to extend beyond Bitcoin and enable diverse applications. Central to the concept of blockchain is decentralization, which involves distributing the blockchain across a network of nodes. Each node possesses the capability to initiate, authenticate, and validate new transactions for inclusion in the blockchain, along with the ability to scrutinize the activities of other network entities. This decentralized architecture, offering tamper-resistant properties and mitigating single-point failure risks, ensures the stability and security of blockchain operations. Blockchain technology encompasses two main types: public (or permissionless) and private (or permission) [26]. In practical applications such as CoT, blockchain can provide robust security features. The paramount feature of blockchain is decentralization, wherein transactions are managed without reliance on a single point of control [27].

Challenges Associated with CoT: Allowing universal participation in IoT and subsequently granting access to all resources through cloud computing presents significant challenges. Numerous issues must be addressed for the success of the CoT, which holds potential benefits for both global advancement and humanity. As CoT ventures into broader commercial applications, the risk posed by malicious actors escalates. In hybrid cloud environments, which incorporate both private and public clouds utilized by enterprises, ensuring security, privacy, and particularly identity protection becomes progressively crucial [28].

Following are some of the main issues.

Protocol support: Various protocols will be employed to connect diverse devices to the Internet. Despite having uniform entities like an IoT sensor, it's conceivable that different protocols such as WirelessHART, ZigBee, IEEE 1451, and 6LOWPAN may be utilized by separate sensors.

Energy efficiency: The widespread utilization of sensor networks and cloud connections leads to extensive data exchange, which consumes significant power. A standard wireless system comprises four components: a sensor device, a processing unit, a transmitter, and a power unit. Power plays a critical role in video sensing, encoding, and decoding processes. Generally, video encoding poses greater challenges compared to decoding, primarily because encoders must evaluate video redundancy to achieve efficient compression [29]. Relying on a battery-based temporary power source that necessitates frequent replacement isn't feasible, especially given the vast number of sensors and low-power devices. Instead, sensors should have the capability to harness electricity from their surroundings, such as from the air, vibrations, and solar energy. Additionally, implementing an efficient sleep mode could prove highly beneficial in conserving energy in this context [30].

Resource allocation: Resource allocation becomes challenging when unforeseen and diverse IoT devices request resources on a cloud. It would be exceedingly difficult to ascertain the precise resource requirements for a particular organization or IoT. The type, quantity, and frequency of data generation need to be aligned with the sensor and its intended purpose. Additionally, sending a test packet from the new node could prove beneficial.

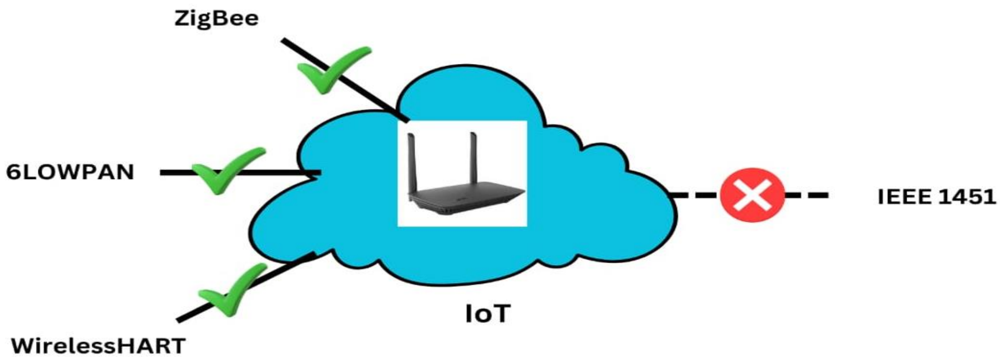


Figure 7. Protocol Support and example (This figure is adapted from Azam et al., 2014 and then edited)

Identity management: Across the Internet, communicating nodes are uniquely identified, necessitating distinct identities when they become part of the IoT. This requirement extends to mobile devices, which must establish identity mapping within the new network they've joined, such as sensor nodes on vehicles and other objects. Assigning IPv6 addresses presents a practical solution in this regard, as the expansive address space of IPv6 can accommodate the needs of ubiquitous networking.

IPv6 deployment: Adopting IPv6 formally would present another challenge if it were to serve as the means to identify communication devices. The advantages of assigning IPv6 addresses to objects would be limited without the implementation of a suitable, standardized, and efficient coexistence method [31].

Service discovery: In the realm of the IoT, the responsibility of discovering new services for consumers lies with the cloud manager or broker. Objects have the flexibility to join or exit the IoT at any given time, with some nodes being portable. This dynamic nature poses challenges in finding new services, understanding their status, and updating service offerings. Complex and extensive IoT deployments may necessitate the presence of an IoT manager, tasked with overseeing the state of IoT nodes, tracking mobile nodes, and maintaining up-to-date information on both existing and newly integrated nodes. To facilitate these tasks, a standardized method of service discovery becomes imperative.

Quality of Service Provisioning: As data volume expands and factors such as diversity and unpredictability come into play, Quality of Service (QoS) becomes a challenge. Any type and amount of data could be generated at any given moment, including potentially critical emergency information. Prioritizing requests dynamically becomes necessary on the cloud side to address these variations in data volume and urgency [32].

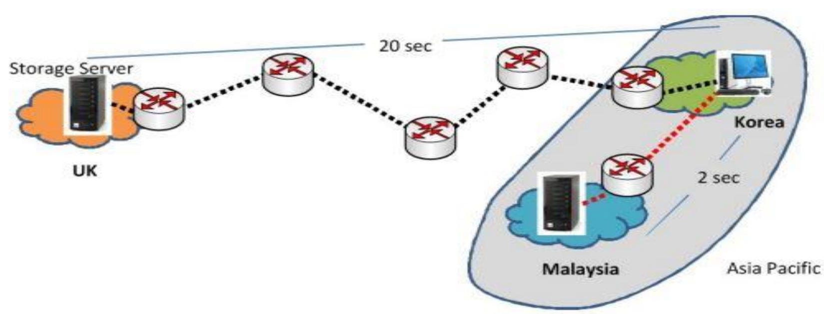


Figure 8. Location of data storage on the cloud (This figure is adapted from Azam et al., 2014)

Location of data storage: Location plays a crucial role in handling sensitive data that is sensitive to latency or jitter. Time-critical data, like video content, should be stored as close to the end-user as possible to minimize access time for large datasets (See Table 2). Virtual storage servers nearest to the user should be designated for multimedia data.

Table 2: summarizing the location of data storage on various cloud platforms

Cloud Provider	Reference	Storage Type	Specific Services/Tools	Description
Amazon Web Services (AWS)	227	Object Storage	Glacier, Amazon S3	Scalable storage for unstructured data, such as media files and backups.
	227	Block Storage	EC2 Instance Store, Amazon EBS	Low-latency storage for applications, virtual machines, and databases.
	227	File Storage	Amazon EFS	Managed file systems for shared access and persistent storage.
Google Cloud	229	Object Storage	Google Cloud Storage, Nearline, Coldline	Storage for unstructured data with high durability and availability.
	229	Block Storage	Google Persistent Disk	Persistent disk storage for containerized applications and VMs.
	229	File Storage	Google File store	File storage service for applications needing a file system interface and shared file storage.
IBM Cloud	230	Object Storage	IBM Cloud Object Storage	Flexible storage for large datasets and unstructured data.
	230	Block Storage	IBM Cloud Block Storage	High-performance storage for demanding databases and workloads.
	230	File Storage	IBM Cloud File Storage	Scalable file storage for shared access and/or data-intensive workloads.
Microsoft Azure	228	Blob Storage	Azure Blob Storage, Archive Storage,	Scalable storage for unstructured data like documents and media files.
	228	Disk Storage	Azure Managed Disks	High-performance storage for VMs, applications, and databases.
	228	File Storage	Azure Files	Managed file shares for on-premises deployments or cloud.
Oracle Cloud	231	Object Storage	Oracle Cloud Object Storage	Scalable storage for storing any type of data in its built-in format.
	231	Block Storage	Oracle Cloud Block Volumes	High-performance storage for databases/enterprise applications.
	231	File Storage	Oracle Cloud File Storage	Managed file storage for high-throughput applications and/or workloads.

Security and privacy: The future landscape of ubiquitous computing will present heightened challenges in terms of security and privacy. Both the cloud and IoT sectors will face issues concerning data security, paralleled by growing concerns surrounding privacy. As reported by The Independent on February 01, 2013, British internet users' personal information stored on prominent "cloud" platforms may be subject to routine surveillance by US authorities.

A. **Fogging and smart gateway-based communication:** As connectivity expands to encompass everything on the Internet and data generation proliferates, there may come a point where uploading data becomes unnecessary or when data is no longer required. In such scenarios, options should be available to either cease data production at the devices/sources or provide instructions to a gateway device regarding when to halt data transmission. This approach is essential to prevent needless consumption of cloud and network resources. To achieve this level of efficiency, a gateway device connected to the IoT endpoint should be granted additional permissions to perform preliminary processing before transmitting data to the cloud and the Internet. The smart gateway device must possess knowledge about the data to be sent and the timing of data transmission, based on feedback provided by the application. Such a gateway device, equipped with these capabilities, is commonly referred to as a Smart Gateway [23; 24]. This approach aids in conserving cloud resources by minimizing the storage of unnecessary data. Data authorized for upload by the gateway is stored in the cloud and utilized to provide services to the user.

Working on a Smart Gateway: Currently, fog computing enjoys widespread utilization globally, particularly in urban settings where it facilitates tasks such as traffic light control and parking space monitoring through centralized systems and applications. Its application extends to resource management as well [34;

33] mobile networks [35] Health Care [36] as well as in smart cities [37]. In the future of network devices, the Smart Gateway holds significant importance [38]. Serving as the link between devices and the internet, it plays a crucial role in facilitating intelligent communication. Unlike traditional gateways, a Smart Gateway optimizes data transmission by filtering out unnecessary information, thereby reducing traffic and enhancing data quality. This capability proves invaluable for ensuring quality assurance and swift data transmission to cloud services. Smart Gateways operate through two modes of communication: single-hop, where sensor nodes and devices connect directly to the Gateway, and multi-hop, where devices are indirectly linked. Integral to IoT architecture, Smart Gateways must intelligently manage various IoT features. Their functions encompass data collection and preprocessing, data purification and structuring, elimination of redundant data, uploading essential data to the cloud, monitoring IoT node energy consumption, ensuring data privacy and security, and overall service management and monitoring. Data collected from IoT devices can either be directly transmitted to the Smart Gateway or relayed through multiple IoTs connected to base stations, which then forward the data to the Smart Gateway [150]. Depending on the communication approach, Smart Gateways can be classified into two types.

1). Less Functionality-based (Single-hop) communication with the smart gateway: This mode of communication is typically deployed on a small scale, where the number of transmitting nodes is limited and each node has a specific role to fulfill. In a single-hop connection, devices and/or sensor nodes are directly linked to the gateway, which receives the data and forwards it to the Fog before transmitting it to the cloud [159]. For instance, in smart healthcare applications, sensors are directly connected to the gateway, enabling swift response and monitoring. The gateway can also relay data to the Fog and then to the cloud in scenarios involving machine-to-machine (M2M) communication. The Smart Gateway, in conjunction with Fog computing, can perform security measures, data enhancement, refinement, and filtering based on the specific requirements of incoming requests.

***2).* More Functionality-based (Multi-hop) communication with the Smart Gateway:** In scenarios where multiple sensors and IoT devices are interconnected, establishing a direct connection to the gateway becomes impractical. Sensor networks and IoT systems often employ their base stations and sink nodes. A multi-hop communication setup arises when the gateway receives data from these base stations and sink nodes. In such situations, nodes are typically more widely distributed. The gateway consequently encounters heterogeneous data, necessitating extensive analysis and processing. Sink nodes enhance security by adding layers to messages, effectively creating a barrier between external entities and the underlying sensors and devices, akin to a black box. This customizable security approach aligns with the requirements of wireless sensor networks (WSNs) and IoT systems. Sink nodes manage sensor networks according to their specific constraints. In such scenarios, the gateway's responsibility lies in handling the diverse data received from IoT devices, heterogeneous devices, and WSNs, necessitating interoperability and transcoding capabilities. These tasks can be accomplished by leveraging fog computing resources or by ensuring the gateway possesses sufficient intelligence. This setup is particularly suited for large-scale WSNs/IoTs, such as automobile trackers, climate controllers, and other mobile objects.

A. **Fog*ging:*** The term "Fog Computing" denotes the concept of bringing networking resources closer to the underlying networks, forming a network that bridges the gap between traditional cloud environments and the edge of the network. With the integration of Fog Computing, the conventional cloud computing paradigm extends toward the network edge, facilitating the development of more robust services and applications. Fog Computing operates as a virtualized model, offering storage, computation, networking services, and traditional cloud functionalities between end nodes within an IoT ecosystem [39]. Unlike traditional cloud setups, Fog Computing is not restricted to the network edge but instead reaches applications and services through dispersed deployments. Fog Computing excels in delivering high-quality streaming to mobile nodes, such as moving vehicles, by strategically positioning access points and proxies along routes and highways. It caters to applications with stringent latency requirements, including gaming, augmented reality, and video streaming. In future smart communication systems, Fog Computing is anticipated to play a pivotal role. Many functions performed by standalone gateways can be more efficiently executed within the context of a co-located smart Gateway or smart network. Additionally, for various services, the deployment of virtual sensor networks and virtual sensor nodes becomes necessary, as physical networks and nodes alone may not suffice. With the presence of Fog Computing alongside smart Gateways or networks, tasks such as data security and privacy, preprocessing, and temporary storage can be seamlessly handled. Fog Computing's localization enables enhanced context awareness and low-latency communication. It facilitates the delivery of real-time data, particularly crucial for delay-sensitive applications such as healthcare services. Before data is forwarded to the cloud for further processing, Fog Computing performs preprocessing tasks and notifies the cloud accordingly.

The varied characteristics of nodes frequently lead to a wide range of data types, presenting challenges regarding transcoding and interoperability. Fog Computing plays a pivotal role in tackling these challenges. Additionally, Fog Computing facilitates the integration of multiple Wireless Sensor Networks (WSNs) and IoT systems by enabling their federation at a centralized point, thus streamlining their connectivity through the Fog. In this way, the creation of rich services comes as a result. Smart Gateway and Fog-based communication architecture can be seen in Figure 3.

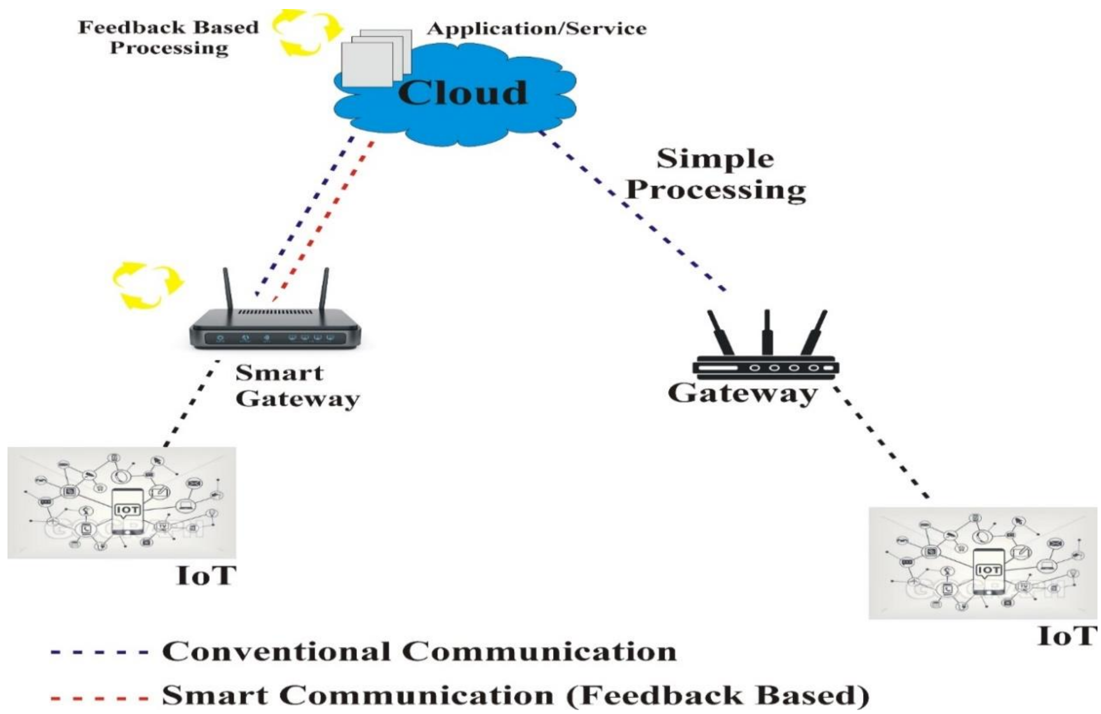


Figure 9. Smart Network with Smart Gateway (This figure is adapted from Azam et al., 2014)

Considering these aspects, Figure 4 illustrates the layered architecture of the Smart Gateway. The virtualization and physical layer oversee the maintenance and management of Wireless Sensor Networks (WSNs), physical nodes, virtual sensor networks, and virtual nodes as per requirements. The monitoring layer is responsible for monitoring the activities of underlying networks and nodes. It tracks which tasks are being executed by each layer, their timing, and the subsequent requirements. Power consumption across devices or nodes is also monitored here to facilitate timely and effective measures. The preprocessing layer handles data management tasks. It undertakes essential steps on collected data, such as filtering and trimming, to extract necessary and meaningful information. Subsequently, Fog resources temporarily store the data. Once the data is forwarded and uploaded to the cloud, and local storage is no longer necessary, it is removed from storage. Wireless Sensor Networks (WSNs) and IoT systems may generate private data, particularly in applications like smart healthcare and ubiquitous healthcare services where patients' confidential information is involved. Additionally, sensitive data such as location-aware data must be securely managed. Hence, the security layer assumes a crucial role in ensuring data protection. Lastly, the transport layer is responsible for uploading data to the cloud, enabling the creation of services for users by the cloud infrastructure.

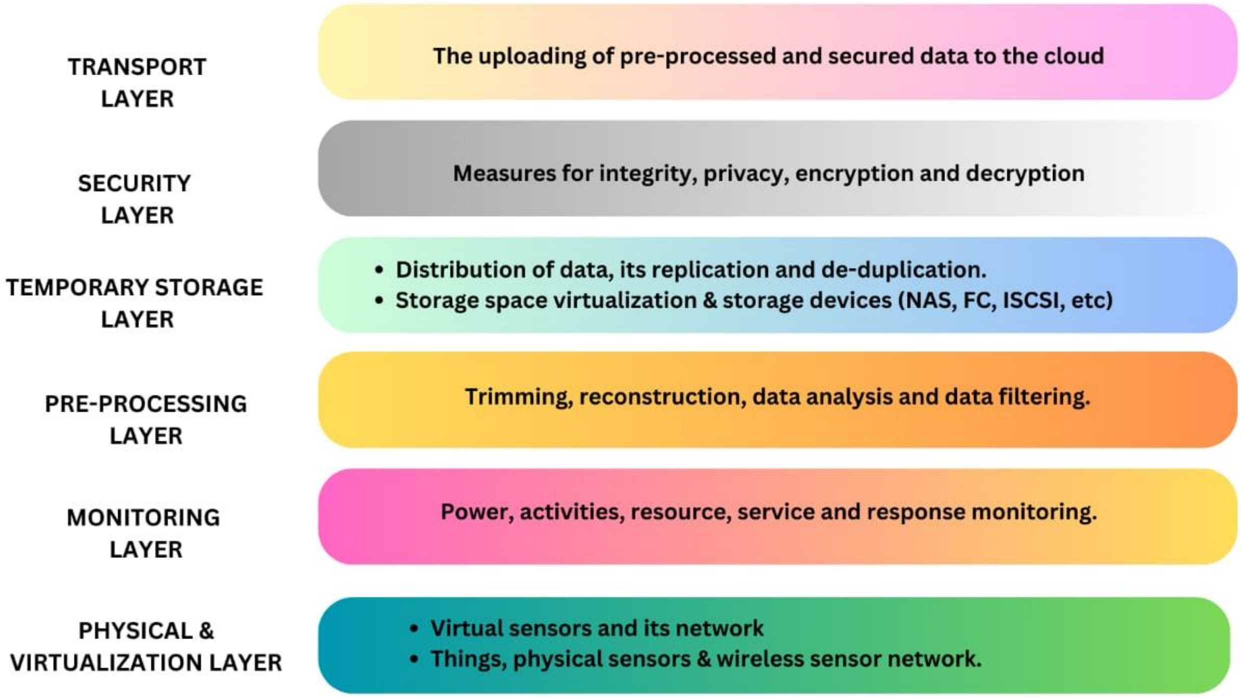
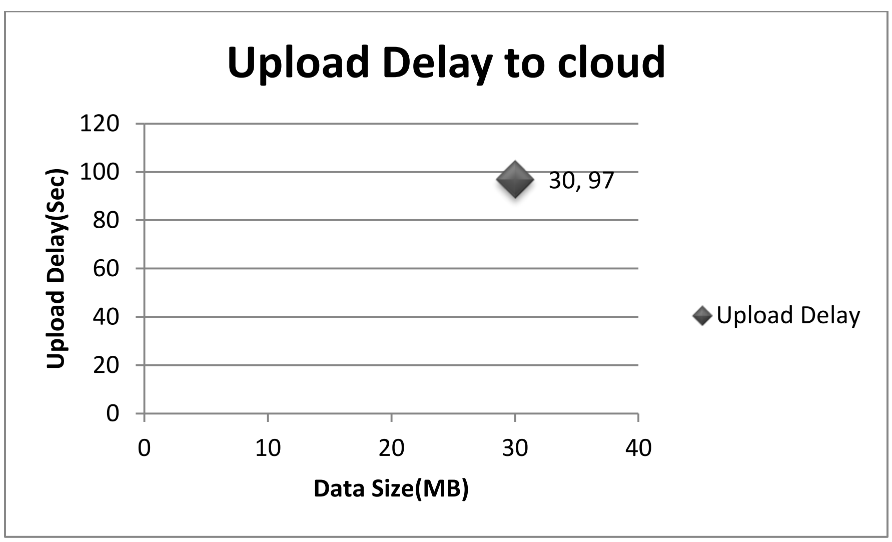


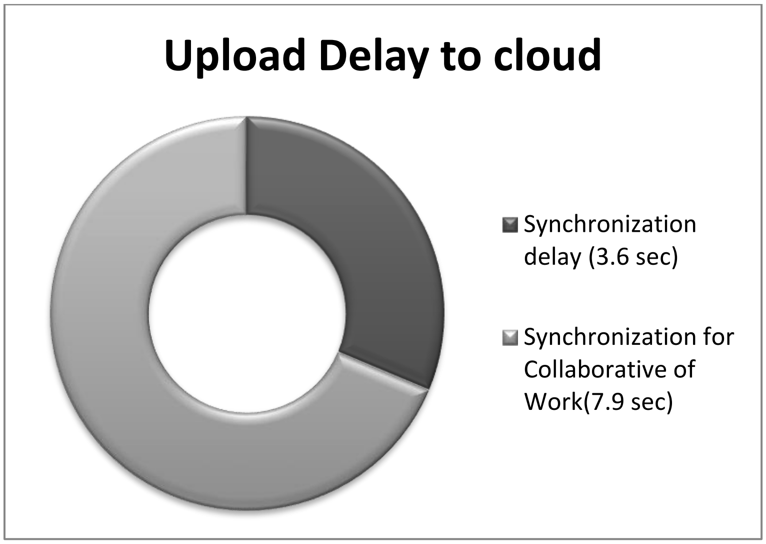
Figure 10. The layered architecture of smart Gateway with smart Gateway/Fog (This figure is adapted from Azam *et al*., 2014 then edited).

III. Evolution: This section focuses on assessing the performance of communication between the cloud and the gateway, conducted within a test environment involving respective devices. Upload Bulk data sets comprised heterogeneous files of various sizes, types, and formats, representing multiple IoT sources. The cloud employs diverse scheduling algorithms such as first-in-first-out and shortest-job-first for handling different file types, influencing overall storage performance. To ensure robustness against varying network conditions, evaluations were conducted exhaustively over six weeks, spanning different times of day, weekends, and weekdays. Ultimately, average results were derived for analysis. For instance, the average time taken to upload a 30MB video file to the cloud was found to be 97 seconds, as depicted in Scatter Graph 1.



When content within the cloud requires relocation or modification of its attributes, the cloud system must reconfigure its URLs, ensuring each file maintains a unique identity or web identity.

Synchronization becomes necessary to accommodate these attribute changes or relocations. In environments where a service is accessed by multiple users or nodes concurrently, a collaborative setup must be established, which demands additional time for synchronization and content updates. The average synchronization time for data is illustrated in Doughnut Chart 1.



Jitter becomes particularly significant during multimedia content transmission, as the cloud must transcode such content to suit the receiving devices. Given that the cloud offers a unified service, it must gather and synchronize various contents generated by different IoT devices. Transcoding operations can impact performance and unexpectedly introduce jitter in traffic. In the second evaluation scenario, bulk data sets were utilized, with each set containing 200MB of data. However, for the sake of simplicity, only the evaluation results for a 15MB bulk data set are presented in Scatter Graph 2 below.

Different types of files are required to be uploaded in the bulk data set, synchronization delay requires more time. Bar chart no. 1 shows the time difference taken by the multimedia 30MB files and bulk data of 15MB which is more than twice in synchronizing file

IV. CoT and its application in various fields: The CoT marks the convergence of two groundbreaking technologies: the IoT and cloud computing. This fusion has created a potent paradigm that enhances traditional IoT solutions by harnessing the scalability, adaptability, and computational prowess inherent in cloud platforms. The resulting CoT concept harbors vast potential across various domains. Our examination will define CoT and illuminate its applications across diverse fields. CoT is essentially a holistic framework that melds IoT devices and sensors with cloud computing infrastructure. In simpler terms, it amplifies the capabilities of conventional IoT by delegating certain tasks to the cloud for processing. This integration facilitates efficient data storage, analysis, and management, thereby augmenting the overall functionality and performance of IoT systems [46; 49; 55].

Key Components of CoT such as IoT Devices and Sensors: These are tangible devices furnished with sensors and actuators, responsible for gathering and transmitting data to the cloud. Connectivity: Dependable and secure communication channels, such as the internet or dedicated networks, facilitate smooth data transmission between IoT devices (such as smartphones, tablets, digital cameras, etc.) and the cloud. Cloud Computing Infrastructure: The CoT ecosystem relies on cloud servers, storage, and computing resources, serving as its foundational elements. These resources enable scalable and on-demand processing of data generated by IoT devices. Data Analytics and Machine Learning: Sophisticated analytics and machine learning algorithms deployed within the cloud are instrumental in extracting valuable insights from the vast volumes of data produced by IoT devices [74; 75].

Applications of CoT: CoTs have numerous applications, particularly in reshaping urban environments into smart cities. IoT devices integrated into infrastructure elements like traffic lights, waste management systems, and energy grids collect data, which is then processed in the cloud [76; 85]. This enables real-time monitoring, optimization, and management of city resources [80].

In the healthcare sector, CoT plays a crucial role in improving patient care and maximizing resource efficiency. Wearable devices and health monitoring sensors gather patient data, which is subsequently sent to the cloud for analysis. Healthcare professionals gain access to real-time information, facilitating prompt interventions and tailored treatment strategies [81; 54; 68].

In industrial environments, CoT plays a vital role, with IoT devices overseeing equipment, monitoring production processes, and guaranteeing operational effectiveness. Cloud-based analytics offer valuable insights into machine health, predictive maintenance, and production streamlining [53].

CoT significantly enhances precision farming practices by utilizing IoT sensors for tasks such as soil monitoring, weather forecasting, and crop health analysis in agriculture. Cloud-based platforms aid farmers in making informed decisions based on data, optimizing resource allocation, and ultimately enhancing crop yields [63; 79).

CoT has revolutionized the retail landscape by employing IoT devices for inventory management, customer analytics, and personalized marketing. Cloud-based solutions empower retailers to streamline operations, enhance supply chain management, and deliver tailored shopping experiences [45].

Introduce the relevance of CoT in animal and veterinary sciences: In the field of animal and veterinary sciences, the integration of the CoT marks a significant advancement, heralding a transformative era for animal care, monitoring, and research [65; 84]. Through the deployment of IoT devices and sensors, veterinarians and researchers can access real-time data on various aspects of animal health, behavior, and environmental conditions [70; 57]. These devices, integrated into wearables or strategically positioned in animal habitats, facilitate continuous monitoring and data collection [66]. Leveraging the cloud-based infrastructure of CoT enables the storage and analysis of extensive datasets, facilitating comprehensive insights into animal well-being, early disease detection, and behavioral patterns [47; 83; 68]. This not only enhances the effectiveness of veterinary care but also opens up new avenues for research, advancing our understanding of the intricate health dynamics across diverse species. The CoT in animal and veterinary sciences represents a significant leap forward in providing holistic, data-driven solutions to enhance animal welfare and deepen our comprehension of their health and behavior.

Highlight the challenges in traditional animal health monitoring: Traditional methods of animal health monitoring encounter numerous challenges that hinder their effectiveness in ensuring the well-being of animals. Manual observation techniques, often conducted infrequently, struggle to capture real-time data and may result in delayed detection of health issues. The subjective nature of human observation introduces inconsistencies, as different observers may interpret animal behavior differently. Resource-intensive practices pose a significant constraint, especially in large-scale farming or research settings, where the labor-intensive nature of traditional monitoring can be costly and inefficient. Moreover, the inability to monitor animals in remote or expansive areas, along with the absence of early warning systems, limits the efficacy of traditional approaches. Cumbersome data management processes, reliant on paper-based records and manual entry, further impede the efficient analysis and sharing of health-related information. These challenges underscore the necessity for more advanced and technologically integrated solutions, such as the CoT, to revolutionize animal health monitoring and management [61; 78].

V. Overview of CoT in Veterinary Sciences

Detail the integration of CoT in veterinary practices: The incorporation of the CoT into veterinary practices marks a significant shift in animal healthcare by harnessing the capabilities of IoT devices and cloud computing. In this framework, wearable sensors and monitoring devices affixed to animals gather real-time data on vital signs, activity levels, and health markers. This data is seamlessly transmitted to the cloud, where it undergoes thorough analysis utilizing advanced algorithms and machine learning techniques. Veterinarians can access a centralized platform, enabling them to remotely monitor animals' health status, identify early signs of illnesses, and take proactive measures. This integration not only enables continuous monitoring but also enhances the efficiency of diagnostics and treatment planning. Furthermore, cloud-based storage ensures secure and accessible health records, fostering collaboration among veterinary professionals. By combining IoT's real-time monitoring capabilities with the computational power of cloud infrastructure, CoT significantly enhances the quality of care, facilitates preventive measures, and advances the overall management of animal health in veterinary practices [68].

Discuss the importance of real-time data in animal health management: Real-time data plays a pivotal role in managing animal health by providing immediate insights into the well-being of animals. In veterinary practices, continuous monitoring through real-time data enables the prompt detection of abnormal behavior, deviations in vital parameters, or early signs of illnesses. This immediacy allows veterinarians to intervene swiftly, offering timely medical attention and enhancing the likelihood of successful treatment outcomes. Additionally, real-time data is crucial for preventive care, as it facilitates the identification of potential health risks before they escalate. In agricultural settings, real-time monitoring of livestock conditions ensures timely responses to environmental factors or disease outbreaks, thereby safeguarding animal welfare and optimizing production efficiency. The significance of real-time data in animal health management transcends diagnostics; it empowers professionals to make informed decisions promptly, contributing to enhanced overall health, reduced mortality rates, and improved resource allocation across various animal care contexts [60].

Explore how CoT improves the efficiency of data collection and analysis: The integration of CoT markedly enhances the efficiency of both data collection and analysis by seamlessly merging IoT devices with cloud computing infrastructure. Unlike traditional systems, which often rely on manual methods for data collection that can be sporadic, CoT enables continuous and real-time acquisition of data from numerous connected sensors and devices. This data is then transmitted to the cloud, where it can be securely stored and scaled up as needed. Leveraging cloud computing resources, such as powerful servers and advanced algorithms, facilitates rapid and efficient analysis of the vast datasets generated by these IoT devices. This streamlined process not only ensures the availability of up-to-date information but also enables the extraction of valuable insights through advanced analytics, machine learning, and predictive modeling. By automating and expediting the data collection and analysis pipeline, CoT optimizes decision-making processes across various domains, fostering a more agile and responsive approach to managing information and enhancing overall system efficiency [67]. In Smart Dairy Farming, IoT plays a crucial role in monitoring resources by connecting various elements within mixed dairy farms, such as buildings (e.g., barns), equipment and vehicles (e.g., milking machines and rural tractors), and even livestock (e.g., dairy cattle). Moreover, by planning, developing, and implementing IoT systems and infrastructure, it is possible to reduce costs associated with monitoring, processing, and networking resources in the Cloud, thereby enhancing service response times and improving the Quality of Service [87].

VI. Wearables and Sensors in Animal Health Monitoring

Examine the role of wearables and sensors in collecting animal health data: Wearables and sensors play a pivotal role in gathering animal health data, providing a non-intrusive and continuous monitoring solution [70]. Specifically designed for animals, these devices are equipped with various sensors that measure vital parameters such as heart rate, temperature, activity levels, and even location [71]. In veterinary practices, wearables offer a real-time stream of data, enabling comprehensive tracking of an animal's health status. For instance, in livestock farming or wildlife conservation, wearables facilitate monitoring of individual and group behaviors, aiding in the early detection of anomalies or signs of distress. The data collected from wearables not only enhances diagnostic precision but also supports preventive care by identifying patterns or deviations that may indicate potential health issues. Through seamless integration with the CoT, these wearables ensure that collected data is transmitted to the cloud for centralized storage and analysis, enabling veterinarians, researchers, and farmers to make informed decisions based on accurate and up-to-date information. The role of wearables and sensors in animal health data collection exemplifies the advancement in monitoring capabilities, promoting proactive and personalized care for animals across various domains [66].

According to Al-Tamimi *et al*. (2019), in their study investigating the efficacy of the Wolff–Chaikoff effect phenomenon in mitigating thermophysiological responses of rats (as an animal model) exposed to acute heat stress, radiotelemetric transmitters linked to compatible receivers and operated by a data acquisition software were utilized. The system permitted real-time measurement (at 30-minute intervals) of core body temperature, locomotive activity, and heart rate simultaneously [85].

Provide examples of wearable devices used in veterinary medicine: Various wearable devices have been developed for veterinary medicine, enhancing animal monitoring and care significantly. For instance, smart collars equipped with sensors like accelerometers and GPS are widely utilized for tracking the activity levels and location of pets, livestock, or wildlife [49; 50]. These collars offer valuable insights into an animal's behavior, aiding in the detection of changes that may indicate health issues or distress [64]. In livestock farming, smart ear tags featuring temperature and movement sensors are employed to monitor the health and well-being of individual animals, allowing farmers to identify potential illnesses early on [73; 56]. Moreover, implantable microchips with temperature and identification capabilities are utilized in research settings to track physiological parameters and individual animal data over extended periods [77; 52]. These examples illustrate the versatility of wearable devices in veterinary medicine, providing a range of monitoring solutions tailored to different animal species and healthcare needs. Integrating such wearables with CoT technologies further enhances their utility by enabling real-time data transmission and cloud-based analytics for more comprehensive insights. In the context of animal behavior, Manteuffel (2019) demonstrated that simple sensors for measuring animal behavior can be advantageous due to their minimal power requirements and straightforward signal interpretation [85].

Discuss the benefits of continuous monitoring for early disease detection: Continuous monitoring of animal health through technologies like wearables and sensors offers a plethora of benefits, with early disease detection being one of the most significant advantages. By continuously gathering and analyzing data on vital parameters, behaviors, and physiological changes, these monitoring systems can identify subtle deviations from normal patterns. Prompt detection of early signs of illness, such as changes in activity levels, abnormal heart rates, or temperature variations, allows veterinarians and caretakers to intervene before the disease progresses to an advanced stage. This proactive approach not only increases the likelihood of successful treatment but also minimizes the impact on the animal's well-being. Early disease detection holds particular importance in agricultural settings, where livestock health directly influences production efficiency, and in wildlife conservation efforts, where swift responses to diseases can prevent outbreaks and safeguard endangered species. When integrated with advanced analytics and cloud-based technologies, continuous monitoring becomes a potent tool for protecting animal health and ensuring timely interventions [59]. Early disease detection can be facilitated by monitoring the amplitude of ruminal contractions in cattle, as they are affected by metabolic diseases such as ruminal acidosis and other illnesses causing discomfort. Wireless sensors designed for rumen pH measurement provide a high-resolution recorder, simplifying the identification of rumen acidosis. These rumen pH sensors enable continuous pH measurement in individual animals [89].

VII. Centralized Data Storage and Collaboration

Explore how CoT enables centralized storage of veterinary data: CoT revolutionizes veterinary data management by facilitating centralized storage. In traditional veterinary practices, patient records, test results, and health histories are often scattered across various physical locations or systems, posing challenges in terms of access and collaboration. However, CoT, utilizing cloud computing infrastructure, enables the secure and centralized storage of vast amounts of veterinary data. This centralized repository not only simplifies data access for veterinarians but also ensures that critical information is consistently updated and available in real-time. Cloud-based storage enhances collaboration among veterinary professionals, enabling seamless sharing of data for consultations, research, or second opinions. Moreover, centralized storage through CoT guarantees data security, as cloud platforms employ robust measures to safeguard sensitive information. This shift in data storage practices not only enhances the efficiency of veterinary practices but also sets the stage for advanced analytics and machine learning applications, promoting a more data-driven and collaborative approach to animal healthcare [62].

Advantages of collaborative data sharing among veterinarians: Collaborative data sharing among veterinarians presents numerous advantages that significantly enhance the quality of animal healthcare. The ability to share and access data in real-time fosters a collaborative approach to diagnosis and treatment planning. Veterinarians can tap into a collective pool of knowledge, experiences, and expertise, leading to more accurate and well-informed decisions. This collaborative exchange proves particularly beneficial in complex or rare cases, where insights from diverse perspectives can be invaluable. Moreover, shared data facilitates seamless communication between veterinary professionals, facilitating quick consultations and second opinions. The cumulative knowledge generated through collaborative data sharing contributes to ongoing research efforts, the development of standardized protocols, and improvements in overall veterinary practices. Additionally, collaborative data sharing supports epidemiological studies, enabling the identification of emerging health trends and the implementation of preventive measures, thereby advancing the field of veterinary medicine and enhancing the well-being of animals [72].

Highlight the role of cloud-based platforms in fostering research collaboration: Collaborative data sharing among veterinarians yields numerous advantages in the realm of animal healthcare. By nurturing a culture of shared information, veterinarians collectively harness a wealth of knowledge and experiences. Access to a centralized repository of veterinary data facilitates informed decision-making, particularly in intricate cases where diverse perspectives are invaluable. Collaborative data sharing enhances diagnostic precision, treatment planning, and overall patient care. It streamlines consultations, enabling veterinarians to seek input from colleagues, specialists, or even remote experts. This collaborative approach not only enhances care quality but also contributes to ongoing research endeavors and the establishment of best practices in veterinary medicine. Furthermore, shared data can be anonymized and aggregated, serving as a basis for epidemiological studies and the detection of emerging trends or disease patterns, thereby propelling the field forward and improving animal health outcomes [51].

VIII. Remote Monitoring and Precision Farming

Detail how CoT facilitates remote monitoring of animals in diverse environments: CoT assumes a crucial role in facilitating remote monitoring of animals across diverse environments by integrating IoT devices and cloud computing. In contexts like wildlife conservation, agriculture, and large-scale farming, strategically placed IoT sensors and wearables gather real-time data on animals' location, health metrics, and behavior [82; 48]. This data is seamlessly transmitted to the cloud, where it can be accessed and analyzed from any location with internet connectivity. The cloud infrastructure serves as a centralized platform for continuous monitoring, enabling caretakers, researchers, and veterinarians to remotely observe and assess the well-being of animals. Whether tracking the movements of endangered species, monitoring livestock on expansive farms, or studying wildlife behavior in remote ecosystems, CoT ensures that essential information is available in real-time, facilitating prompt interventions and deepening our understanding of animals in various environments [58].

Discuss the impact of CoT on precision farming practices in veterinary sciences: CoT is revolutionizing precision farming practices within veterinary sciences by introducing advanced monitoring capabilities and data-driven decision-making processes. Through the utilization of IoT devices like smart collars or implantable sensors on livestock, continuous data collection on animal health, behavior, and environmental conditions occurs. This real-time data is then transmitted to the cloud for analysis, yielding valuable insights. This enables veterinarians and farmers to make informed decisions regarding individual animal care, herd management, and resource optimization. CoT greatly enhances precision farming by facilitating remote livestock monitoring, early detection of health issues, and targeted interventions. Consequently, this results in enhanced animal welfare, optimized breeding programs, and more efficient resource allocation in agriculture, ultimately fostering sustainability and productivity within veterinary practices operating within the realm of precision farming [69].

IX. Use of IoT based systems for precise monitoring of poultry farm management: Poultry farming stands as a significant global industry, with the production and consumption of chicken meat experiencing rapid growth [40]. However, the poultry production sector, particularly concerning broiler chickens, faces substantial challenges from climate change due to the birds' susceptibility to environmental changes [41]. Implementing continuous monitoring and regulation of factors such as temperature, humidity, ammonia, carbon monoxide, carbon dioxide, and other critical parameters within poultry sheds can aid in mitigating adverse environmental impacts and optimizing conditions for both chicken health and meat production [42].

Recent research endeavors have concentrated on the development of intelligent IoT based systems to facilitate real-time monitoring and data-centric management of poultry farms. These proposed systems incorporate wireless sensor networks to gather environmental data, transmit it to central servers, and generate alerts when preset thresholds are surpassed [43; 44]. These sensors are capable of monitoring various parameters including temperature, humidity, gases such as CO_2 and NH_3, water levels, and more. Furthermore, the integration of cloud computing, machine learning, and automation techniques enables the analysis of collected data and the automatic control of farm equipment. Lashari *et al*. [43; 119; 156] illustrate an IoT system employing custom technology for this purpose. Arduino-based sensor nodes equipped with LoRa wireless communication were deployed in a commercial poultry farm located in Pakistan. These nodes monitored various parameters including temperature, humidity, oxygen levels, CO_2, CO, and NH_3 concentrations. The system reported that temperatures and humidity remained within acceptable ranges, CO_2 levels were elevated but not hazardous, and NH_3 concentrations remained consistently low. Real-time data and alerts provided by this system allowed farm managers to optimize conditions for the health and growth of broilers. This research underscores the advantages of IoT-based monitoring in promoting sustainability within poultry production.

In essence, IoT-enabled smart systems hold the potential for enhancing poultry farm management, boosting productivity, ensuring the welfare of birds, and mitigating environmental impacts. With further advancements in IoT, automation, and data analytics techniques, the evolution towards next-generation "smart farming" can foster more sustainable practices within the global poultry industry (see Table 3).

Using modern technology in poultry and livestock farming: In the 21st century, the global population growth rate averages about 1.14 annually, with an estimated 784 million people experiencing hunger [91]. Following the COVID-19 pandemic, there was optimism that the world would strive for improvement [116; 91]. However, challenges related to food security and world hunger persistently increased. Employing modern farm systems to enhance the production of animal protein, such as meat, milk, and eggs, can reduce production costs through the utilization of this technology [90, 111, 112; 115]. Mechanized remote monitoring and identification of animal welfare indicators through real-time data analysis of body metrics may advance biological measurements in livestock and poultry [92]. Numerous studies have assessed physiological parameters using sensing technology. For instance, in cattle farming, various sensors such as video and photo sensors, infrared thermography, motion sensors, and wearable devices like collars and halter sensors were utilized to evaluate behaviors related to rutting span, back posture, eye orbital temperature, grazing, feeding, lameness, and respiratory rate [93, 94, 95, 96, 97, 98, 99, 100, 101, 102]. Similarly, in small ruminant research involving sheep and goats, digital infrared thermal imaging and accelerometers were employed to measure eye and muzzle temperature and body acceleration [103]. In monogastric animal farming such as pigs and broilers, researchers utilized various sensors including pressure mats, accelerometers, infrared cameras, and microfluidics-based biosensors to measure parameters such as gait, locomotion, drinking behavior, body temperatures, conformation, posture, movement, and vocalizations [104, 105, 106, 107, 108, 109, 110; 163]. In summary, modern technology enables the evaluation of various biological, metabolic, physical, immunological, and behavioral parameters associated with animal physiology, aiding in improving performance quality, quantity, and profitability. This includes monitoring feed and water intake behavior, emotional contagion, heart rate, respiration rate, core temperature, metabolism, immune function, diseases, vocalizations, movement, and posture to enhance overall performance [133;]

X. Overview of CoT in Food Sciences

Precision Agriculture: CoT enables precision agriculture by integrating IoT sensors, drones, and satellite imagery with cloud-based analytics. Farmers can monitor soil moisture levels, nutrient content, and crop health in real time, allowing for optimized irrigation, fertilization, and pest control (See Table 4). This leads to higher crop yields, improved resource efficiency, and reduced environmental impact [149].

Table 3: Precision farming practices in animal sciences.

Application	Researchers	Tools/Software/Instruments	Function
Health Monitoring	221; 209	CowManager, Smartbow, Allflex Livestock Intelligence	Monitor vital signs, and activity intensities, and act as health indicators for early detection of diseases
Reproductive Management	215; 222	MooMonitor+, Heatime, SenseHub	Monitor/manage reproductive health i.e. pregnancy diagnosis and estrus detection.
Nutritional Management	219; 208	DairyComp 305, TMR Tracker, FeedWatch	These are precision feeding systems that optimize the feed composition and deliver feeds according to each animal's needs.
Environmental Control	207; 211	VES-Artex, ThermoPlus, ClimateMinder	These systems control environmental factors like temperature, relative humidity, and ventilation.
Behavioral Analysis	217; 212	IceQube, EarTags, Nedap Livestock Management	Monitor animals' behavior for goodness and welfare, identify stress factors, and improve managemental factors.
Genetic Improvement	226; 223	CLARIFIED, GeneSeek, Breedplan	Analyze genetics data to improve breeding programs and exploit desirable traits.
Disease Surveillance	225; 214	Vet-Sentry, Zoetis Bioportal, Biocheck.Ugent	Real-time monitoring systems and data analytics that detect/manage disease outbreaks.
Precision Grazing	210; 218	Agersens eShepherd, PastureMap, Gallagher SmartFence	Manage grazing patterns and use of pastures to enhance forage availability to animals and improve animal health.
Precision Medicine	213; 220	Idexx Laboratories, VetMax, Zoetis Vetscan	Improving medical treatments to individual animals based on behavioral, genetic, and health data.
Automated Milking Systems (AMS)	216; 224	DeLaval VMS, Lely Astronaut, GEA DairyRobot	These are robotic systems that automate the milking process, track cow health, and monitor milk quality.

Table 4: Precision agriculture Production

Application	Scientists and coworkers	Software/Instruments	Function
Soil Monitoring	194	Sentek Drill & Drop, Teralytic, AquaSpy	Monitoring soil conditions (moisture, pH, nutrient levels) for optimized crop management.

Variable Rate Technology (VRT)	191; 205	John Deere Rate Controller, Raven Viper 4+	Application of inputs (seeds, fertilizers, pesticides) at variable rates based on field data.
Crop Monitoring	197; 201; 206	FieldAgent, DroneDeploy, CropX	Remote sensing technologies to monitor crop health, growth, and development.
Irrigation Management	193; 188	Hortau, Netafim, Reinke VRI	Optimizing irrigation schedules and amounts based on soil and weather data.
Yield Monitoring	195; 190	Trimble Yield Monitoring, Ag Leader Yield Monitor	Tracking and analyzing crop yields during harvest to assess field variability.
Farm Management Software	189; 195; 199	Granular, FarmLogs, Climate FieldView	Integrating various data sources for comprehensive farm management and decision support.
Pest and Disease Management	197; 201	TrapView, Xarvio, Taranis	Identify and manage pest and disease outbreaks using data analytics and remote sensing.
Drones/UAVs	197; 203	Parrot Bluegrass, DJI Agras, SenseFly eBee	Employing drones for detailed field surveillance and data collection.
Satellite Imagery	Houborg & McCabe, 2018	GeoSys, Planet Labs, SatSure	Using satellite images for large-scale monitoring and management of agricultural fields.
Automated Machinery	Griffin et al., 2017	Case IH AFS, John Deere AutoTrac, New Holland IntelliSteer	Utilizing GPS-guided machinery for planting, harvesting, and other field operations.
Weather Forecasting	204	WeatherBug, DTN, IBM Weather Company	Using precise weather data and forecasts to make up-to-date farming decisions.

Smart Greenhouses: IoT sensors deployed in greenhouses can monitor environmental parameters such as temperature, humidity, light intensity, and CO2 levels. Cloud-based analytics analyze this data to create optimal growing conditions for crops, resulting in higher productivity and quality. Automated systems can also adjust environmental controls and irrigation schedules based on real-time data, reducing manual labor and operational costs [125; 148].

Food Safety and Quality Control: CoT facilitates continuous monitoring of food safety parameters throughout the production and distribution process. Sensors embedded in equipment and packaging detect contaminants, spoilage, and deviations from quality standards (See Table 5). Cloud-based analytics analyze this data to identify potential risks and ensure compliance with regulatory requirements, ultimately enhancing food safety and consumer confidence [143].

Supply Chain Visibility: CoT provides end-to-end visibility into the food supply chain, from farm to fork. IoT sensors track the location, temperature, and condition of food products during transportation and storage. Cloud-based platforms aggregate and analyze this data, enabling stakeholders to optimize logistics, reduce waste, and respond quickly to quality issues or recalls [144].

Personalized Nutrition: CoT enables personalized nutrition solutions by leveraging IoT devices, wearable sensors, and mobile apps. Individuals can track their dietary intake, physical activity, and health metrics in real-time. Cloud-based algorithms analyze this data to provide personalized diet recommendations and behavioral insights, helping people make healthier food choices and manage chronic conditions [145].

Food Traceability and Authentication: CoT enhances food traceability and authentication through the use of blockchain technology and IoT devices. Each step in the food supply chain is recorded and verified on a decentralized ledger, ensuring transparency and integrity. Consumers can scan QR codes or NFC tags on product packaging to access detailed information about its origin, production methods, and safety certifications [146].

Smart Packaging and Labeling: IoT-enabled smart packaging and labeling solutions provide real-time information about food freshness, storage conditions, and expiration dates. Sensors embedded in packaging detect changes in temperature, humidity, and gas composition, alerting consumers to potential spoilage or contamination. Cloud-based platforms also enable interactive packaging features, such as augmented reality experiences and digital content delivery [147]. CoT technology offers tremendous opportunities to improve food safety, quality, sustainability, and consumer engagement in the field of food sciences. By leveraging IoT sensors, cloud-based analytics, and smart connected devices, food companies can optimize production processes, enhance supply chain visibility, and deliver personalized experiences to consumers. However, it's essential to address challenges related to data privacy, security, and interoperability to realize the full potential of CoT in food sciences.

X. Conclusions and Future Recommendations: The present review intends to determine the expansion of IoTs and integration with cloud computing, for the efficient utilization of resources as well as for the provisioning of more useful and enhanced services to the users. For improved and rapid service provision, preprocessing and trimming the data earlier to transport it to the cloud is important. The present progress/revolution in computer science has communicated based on Smart Gateway, with Fog computing, to help lessen the burden on the cloud and with the purpose of smart communication. Communication overhead is also alleviated by this for the main network. Such an approach allows the cloud to offer improved services for the users and Fog computing can help to make real-time delay-sensitive applications from normal communication. This model of CoT, with Fog computing and smart gateway-based smart communication, will give a good portfolio of services. Moreover, an assessment of performance based on numerous parameters and with a comprehensive method will help to make rapid progress in digital services. In conclusion, the adoption of the CoT in animal and veterinary sciences brings forth a transformative wave of benefits. CoT seamlessly integrates IoT devices, wearables, and cloud computing, revolutionizing the way animals are monitored, diagnosed, and cared for. The real-time data collection and analysis capabilities empower veterinarians, researchers, and farmers with immediate insights into animal health, enabling early disease detection, timely interventions, and improved overall well-being. The centralized storage of veterinary data facilitates collaboration, standardization, and data-driven decision-making. CoT's impact extends to diverse environments, allowing for remote monitoring of animals in wildlife conservation, precision farming, and large-scale agriculture. Furthermore, the technology supports precision farming practices, optimizing resource utilization and contributing to sustainable and efficient agricultural practices. In essence, the adoption of CoT in animal and veterinary sciences not only elevates the quality of care but also paves the way for advancements in research, collaboration, and the overall management of animal health across various domains.

Table 5: An overview of the CoT in food sciences

Application	Researchers	Tools/Software	Description
Supply Chain Management	182; 172	IBM Food Trust, Oracle Cloud SCM, SAP Cloud Platform	CoT platforms manage and track the food supply chain from farm to table.
Inventory Management	170; 177	ClearMetal, Microsoft Azure IoT Hub, Tive	CoT systems manage food stock rotation, inventory levels, and expiration dates.
Food Safety and Quality Control	169; 178	FoodLogiQ, SafeTraces, SmartSense	Cloud platforms and Sensors monitor food quality and safety parameters in real-time.
Predictive Maintenance	176; 173	GE Predix, Siemens MindSphere,	Predicting maintenance of types of equipment of food processing using IoT data analyzed in the cloud.
Traceability	181; 168	Honeywell Traceability Solutions, TraceLink	CoT allows detailed traceability of food products by the supply chain.
Energy Management	185; 179	EnerNOC, Schneider Electric EcoStruxure,	Enhance energy efficiency use in food storage and processing services through CoT.
Smart Farming	186; 184	Climate FieldView, John Deere Operations Center	Cloud technologies and Integrating IoT for agriculture precision and practices of smart farming.
Environmental Monitoring	168; 174	TempTRIP, Monnit, Sensitech	Monitor environmental factors/conditions such as temperature, relative humidity, and CO_2 concentrations in food storage and food processing facilities.
Waste Management	171; 180	Spoiler Alert, Wasteless, Leanpath	Manage food waste and optimize waste-reducing approaches using CoT.
Consumer Engagement	183; 175	Provenance, ripe.io, IBM Blockchain	Enhance consumer commitment through translucent information on food sourcing and production.

REFERENCES

[1] Miao Wu et. al., “Research on the architecture of Internet of things”, in the proceedings of 3rd International Conference on Advanced Computer Theory and Engineering, 20-22 August, 2012, Beijing, China

[2] Gerd Kortuem, Fahim Kawsar, Daniel Fitton, and Vasughi Sundramoorthi, “Smart Objects and

Building Blocks of Internet of Things", IEEE Internet Computing Journal, volume 14, issue 1, pp. 44-51, Jan.-Feb., 2010

[3] Krasniqi, X. and E. Hajriz. 2016. Use of IoT Technology to Drive the Automotive Industry from Connected to Full Autonomous Vehicles. IFAC-Papers OnLine 49-29: 269–274

[4] Darshan K R and K R Anandakumar.2015.A Comprehensive Review on Usage of IoT in Healthcare System. International Conference on Emerging Research in Electronics, Computer Science and Technology.

[5] Ahmad Sinali Abdulraheem, Azar Abid Salih, Abdulrahman Ihsan Abdulla, Mohammed A. M. Sadeeq, Nareen O. M. Salim, Hilmi Abdulla6, Farhad M. Khalifa, Rebin Abdullah Saeed. Home Automation System based on IoT. Technology Reports of Kansai University, 62(5): 2453-2464.

[6] IoT and the Energy Sector

[7] Titovskaia, N V *et al* 2020 IOP Conf. Ser.: Earth Environ. Sci. 548 032021

[8] Rafiullah Khan, Sarmad Ullah Khan, Rifaqat Zaheer, and Shahid Khan. "Future Internet: The Internet of Things Architecture,Possible Applications and Key Challenges", in the proceedings of 10^{th} International Conference on Frontiers of Information Technology, Islamabad, Pakistan, 17-19.

[9] Dieter Uckelamann, Mark Harrison, and Floria Michahelles. 2011. "Architecting the Internet of Things," Springer-Verlag Berlin Heidelberg.

[10] Bandyopadhyay, D., & Sen, J. (2011). Internet of things: Applications and challenges in technology and standardization. Wireless personal communications, 58(1), 49-69.

[11] CTV Deadly Fakes- CTV News. http://www.ctv.ca/servlet/ArticleNews/story/CTVNews/20020306/ ctvnews848463.

[12] Caesar Wu, Rajkumar Buyya and Kotagiri Ramamohanarao.2018. Cloud Computing Market Segmentation. Special Session on Software Engineering for Service and Cloud Computin. Accessed at file:///C:/Users/Admin/AppData/Local/Temp/Rar$DIa0.915/10%20cloud%20marketing.pdf.

[13] Ioannis Nanos, Vicky Manthou, and Efthimia Androutsou Cloud Computing Adoption Decision in E-government. Accessed at file:///C:/Users/Admin/AppData/Local/Temp/Rar$DIa0.392/11%20cloud%20use%20in%20e%20government.pdf.

[14] Keng-Boon Ooi , Voon-Hsien Lee , Garry Wei-Han Tan , Teck-Soon Hew , Jun-Jie Hew. 2017. Cloud computing in manufacturing: The next industrial revolution in Malaysia?, Expert Systems With Applications, doi: 10.1016/j.eswa.2017.10.009.

[15] Lila Rajabiona,⁎, Abdusalam Abdulla Shaltookib, Masoud Taghikhahc, Amirhossein Ghasemid, Arshad Badfare. 2019. Healthcare big data processing mechanisms: The role of cloud computing. International Journal of Information Managemen, 49: 271-289.

[16] QUADRI NOORULHASAN NAVEED1, MOHAMED RAFIK NOOR MOHAMED QURESHI 2, ASADULLAH SHAIKH 3, (TCSE, IEEE), ALHUSEEN OMAR ALSAYED4, SUMAYA SANOBER5, AND KHALID MOHIUDDIN. 2019. Evaluating and Ranking Cloud-Based E-Learning Critical Success Factors (CSFs) Using Combinatorial Approach. IEEE access, volume9.doi10.1109/ACCESS.2019.2949044

[17] Shuai Zhang et. al., "Cloud Computing Research and Development Trend", in the proceedings of International Conference on Future Networks, 22-24 Jan., 2010, Sanya, China.

[18] W. Ma et. al., "The Survey and Research on Application of Cloud Computing", in the proceedings of 7th International Conference on Computerl Science and Education, 02-04 November, 2012, Wuyishan Mountain, China.

[19] Jadeja, Y. et. al., "Cloud Computing - Concepts, Architecture and Challenges", in the proceedings of International Conference on Computing Electronics and Electrical Technologies, 21-22 March, 2012, Nagercoil, India.

[20] Minqi Zhou et. al., "Services in the Cloud Computing Era: A Survey", in the proceedings of 4th International Universal Communications Symposium, 18-19 October, 2010, Beijing, China.

[21] Jayavardhana Gubbi, Rajkumar Buyya, Slaven Marusic, and Marimuthu Palaniswami, "IoT: A Vision, Architectural Elements, and Future Directions", Technical Report CLOUDS-TR-2012-2, July 2012.

[22] Dave Evans, "The Internet of Things How the Next Evolution of the Internet Is Changing Everything", Whitepaper, Cisco Internet Business Solutions Group (IBSG), April 2011.

[23] Mohammad Aazam, Eui-Nam Huh, "Inter-Cloud Architecture and Media Cloud Storage Design Considerations", in the proceedings of 7^{th} IEEE CLOUD, Anchorage, Alaska, USA, 27 June - 02 July, 2014.

[24] Mohammad Aazam, Eui-Nam Huh, "CoT: Integrating Internet of Things with Cloud Computing and the Issues Involved", in the proceedings of 11th IEEE International Bhurban

Conference on Applied Sciences and Technology, Islamabad, Pakistan, 14-18 January, 2014.

[25] Lin, J., W. Yu, N. Zhang, X. Yang, H. Zhang, and W. Zhao, "A surveyon internet of things: Architecture, enabling technologies, security and privacy, and applications," IEEE Internet of Things Journal, vol. 4, no. 5, pp. 1125–1142, 2017.

[26] Dinh, T. T. A., R. Liu, M. Zhang, G. Chen, B. C. Ooi, and J. Wang, "Untangling blockchain: A data processing view of blockchain systems," IEEE Transactions on Knowledge and Data Engineering, vol. 30, no. 7, pp. 1366–1385, 2018.

[27] Liu J and Z. Liu, "A survey on security verification of blockchain smart contracts," IEEE Access, 2019.

[28] Jayavardhana Gubbi, Rajkumar Buyya, Slaven Marusic, and Marimuthu Palaniswami, "IoT: A Vision, Architectural Elements, and Future Directions", Technical Report CLOUDS-TR 2012-2, July 2012.

[29] Yen-Kuang Chen, "Challenges and Opportunities of Internet of Things", in the proceedings of 17th Asia and South Pacific Design Automation Conference, 30 Jan. – 02 Feb., 2012, Santa Clara, CA, USA.

[30] Dave Evans, "The Internet of Things How the Next Evolution of the Internet Is Changing Everything", Whitepaper, Cisco Internet Business Solutions Group (IBSG), April 2011.

[31] Mohammad Aazam and Eui-Nam Huh, "Impact of IPv4-IPv6 Coexistence in Cloud Virtualization Environment", Annals of Telecommunications, vol. 68, DOI: http://dx.doi.org/10.1007/s12243-013-0391-6, August 2013.

[32] Mohammad Aazam, Adeel M. Syed, Eui-Nam Huh, "Redefining Flow Label in IPv6 and MPLS Headers for End to End QoS in Virtual Networking for Thin Client", in the proceedings of 19th IEEE APCC, Bali, Indonesia, 29-31 August, 2013

[33] Mostafa Ghobaei-Arani & Alireza Souri & Ali A. Rahmanian. Resource Management Approaches in Fog Computing: a Comprehensive Review. J Grid Computing https://doi.org/10.1007/s10723-019-09491-1

[34] Tian Wanga ,Yuzhu Lianga, Weijia Jiab, Muhammad Arif, Anfeng Liud, Mande Xiee (2019). Coupling resource management based on fog computing in smart city systems from external paper. Journal of Network and Computer Applications. 135: 11-19.

[35] Yiqing Zhou, Lin Tian, Ling Liu, and Yanli Qi. 2019. Fog Computing Enabled Future Mobile Communication Networks: A Convergence of Communication and Computing. Accessed on file:///C:/Users/Admin/AppData/Local/Temp/Rar$DIa0.216/25%20fog%20in%20mobile%20networks.pdf.Doi 10.1109/MCOM.2019.1800235

[36] Ammar Awad Mutlag,Mohd Khanapi Abd Ghani,N. Arunkumar,Mazin Abed Mohamed, Othman Mohd. 2019. Enabling technologies for fog computing in healthcare IoT systems. DOI https://doi.org/10.1016/j.future.2018.07.049

[37] Hadi Zahmatkesha,*, Fadi Al-Turjma Fog computing for sustainable smart cities in the IoT era: Caching techniques and enabling technologies,an overview. Sustainable Cities and Society, 59: 1021-39.

[38] FeiDing, AiguoSong, EnTong, and Jianqing Li. 2016 A Smart Gateway Architecture for Improving Efficiency of Home Network Applications. Hindawi Publishing Corporation Journal of Sensors Volume, Article ID 2197237, 10 pages

[39] Flavio Bonomi, Rodolfo Milito, Jiang Zhu, Sateesh Addepalli, "Fog Computing and Its Role in the Internet of Things", in the proceedings of ACM SIGCOMM, August 17, 2012, Helsinki, Finland. 470

[40] **Chodkowska, K.A., Wódz, K., & Wojciechowski, J. (2022).** Sustainable future protein foods: the challenges and the future of cultivated meat. Foods, **11(24).** https://doi.org/10.3390/foods11244008

[41] **Janczak, A.M., & Riber, A.B. (2015).** Review of rearing-related factors affecting the welfare of laying hens. Poultry Science, **94(7)**, 1454-1469. https://doi.org/10.3382/ps/pev123

[42] **Ammad-Uddin, M., Ayaz, M., Aggoune, E.-H., & Sajjad, M. (2014).** Wireless sensor network: a complete solution for poultry farming. In 2014 IEEE 2nd International Symposium on Telecommunication Technologies (ISTT) (pp. 321-325). IEEE.

[43] **Lashari, M.H., Karim, S., Alhussein, M., Hoshu, A.A., Aurangzeb, K., & Anwar, M.S. (2023).** Internet of Things-based sustainable environment management for large indoor facilities. PeerJ Computer Science, 9, e1623. https://doi.org/10.7717/peerj-cs.1623

[44] **Archana, M., Uma, S., & Babu, T.R. (2018).** A survey on: monitoring of poultry farm using IoT. International Research Journal of Engineering and Technology, **5(4)**, 4635-4638.

[45] Abu Ghazaleh, M., & Zabadi, A. M. (2020). Promoting a revamped CRM through Internet of Things and Big Data: an AHP-based evaluation. *International journal of organizational analysis*, *28*(1), 66-91.

[46] Alhaidari, F., Rahman, A., & Zagrouba, R. (2023). CoT: architecture, applications and challenges. *Journal of Ambient Intelligence and Humanized Computing*, *14*(5), 5957-5975.

[47] Aloulou, H., Mokhtari, M., & Abdulrazak, B. (2020). Pilot site deployment of an IoT solution for older adults' early behavior change detection. *Sensors*, *20*(7), 1888.

[48] Atalla, S., Tarapiah, S., Gawanmeh, A., Daradkeh, M., Mukhtar, H., Himeur, Y., ... & Daadoo, M. (2023). IoT-Enabled Precision Agriculture: Developing an Ecosystem for Optimized Crop Management. *Information*, *14*(4), 205.

[49] Babu, S. M., Lakshmi, A. J., & Rao, B. T. (2015, April). A study on cloud based Internet of Things: CloudIoT. In *2015 global conference on communication technologies (GCCT)* (pp. 60-65). IEEE.

[49] Bailey, D. W., Trotter, M. G., Knight, C. W., & Thomas, M. G. (2018). Use of GPS tracking collars and accelerometers for rangeland livestock production research. *Translational Animal Science*, *2*(1), 81-88.

[50] Brennan, J., Johnson, P., & Olson, K. (2021). Classifying season long livestock grazing behavior with the use of a low-cost GPS and accelerometer. *Computers and Electronics in Agriculture*, *181*, 105957.

[51] Bykov, V. Y., & Shyshkina, M. P. (2018). The conceptual basis of the university cloud-based learning and research environment formation and development in view of the open science priorities. *Інформаційні технології і засоби навчання*, (68,№ 6), 1-19.

[52] Chung, H., Li, J., Kim, Y., Van Os, J. M., Brounts, S. H., & Choi, C. Y. (2020). Using implantable biosensors and wearable scanners to monitor dairy cattle's core body temperature in real-time. *Computers and electronics in agriculture*, *174*, 105453.

[53] da Silva, A. F., Ohta, R. L., dos Santos, M. N., & Binotto, A. P. (2016). A cloud-based architecture for the internet of things targeting industrial devices remote monitoring and control. *Ifac-Papersonline*, *49*(30), 108-113.

[54] Dang, L. M., Piran, M. J., Han, D., Min, K., & Moon, H. (2019). A survey on internet of things and cloud computing for healthcare. *Electronics*, *8*(7), 768.

[55] Distefano, S., Merlino, G., & Puliafito, A. (2012, July). Enabling the CoT. In *2012 Sixth International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing* (pp. 858-863). IEEE.

[56] Džermeikaitė, K., Bačėninaitė, D., & Antanaitis, R. (2023). Innovations in Cattle Farming: Application of Innovative Technologies and Sensors in the Diagnosis of Diseases. *Animals*, *13*(5), 780.

[57] Halachmi, I., Guarino, M., Bewle y, J., & Pastell, M. (2019). Smart animal agriculture: application of real-time sensors to improve animal well-being and production. *Annual review of animal biosciences*, *7*, 403-425.

[58] Hart, J. K., & Martinez, K. (2006). Environmental sensor networks: A revolution in the earth system science?. *Earth-Science Reviews*, *78*(3-4), 177-191.

[59] Hassanalieragh, M., Page, A., Soyata, T., Sharma, G., Aktas, M., Mateos, G., ... & Andreescu, S. (2015, June). Health monitoring and management using Internet-of-Things (IoT) sensing with cloud-based processing: Opportunities and challenges. In *2015 IEEE international conference on services computing* (pp. 285-292). IEEE.

[60] Holmstrom, L. K., & Beckham, T. R. (2017). Technologies for capturing and analysing animal health data in near real time. *Rev Sci Tech*, *36*, 525-538.

[61] Hovi, M., Sundrum, A., & Thamsborg, S. M. (2003). Animal health and welfare in organic livestock production in Europe: current state and future challenges. *Livestock production science*, *80*(1-2), 41-53.

[62] Iqbal, N., Jamil, F., Ahmad, S., & Kim, D. (2021). A novel blockchain-based integrity and reliable veterinary clinic information management system using predictive analytics for provisioning of quality health services. *IEEE Access*, *9*, 8069-8098.

[63] Islam, S., Jamwal, S., & Mir, M. H. (2021). Leveraging fog computing for smart internet of things crop monitoring farming in Covid-19 era. *Annals of the Romanian Society for Cell Biology*, *25*(6), 10410-10420.

[64] Jukan, A., Masip-Bruin, X., & Amla, N. (2017). Smart computing and sensing technologies for animal welfare: A systematic review. *ACM Computing Surveys (CSUR)*, *50*(1), 1-27.

[65] Karthick, G. S., Sridhar, M., & Pankajavalli, P. B. (2020). Internet of things in animal healthcare (IoTAH): review of recent advancements in architecture, sensing technologies and real-time monitoring. *SN Computer Science*, *1*, 1-16.

[66] Makiyama, K., Nakagawa, K., Katayama, M., Nagasawa, M., Sezaki, K., & Kobayashi, H. (2015). Synchronization of Peripheral Vision and Wearable Sensors for Animal-to-Animal Interaction. In *Human-Computer Interaction: Interaction Technologies: 17th International Conference, HCI International 2015, Los*

Angeles, CA, USA, August 2-7, 2015, Proceedings, Part II 17 (pp. 753-764). Springer International Publishing.

[67] Malik, A., & Om, H. (2018). Cloud computing and internet of things integration: Architecture, applications, issues, and challenges. *Sustainable cloud and energy services: Principles and practice*, 1-24.

[68] Manocha, A., Kumar, G., Bhatia, M., & Sharma, A. (2023). IoT-inspired machine learning-assisted sedentary behavior analysis in smart healthcare industry. *Journal of Ambient Intelligence and Humanized Computing*, *14*(5), 5179-5192.

[69] Morrone, S., Dimauro, C., Gambella, F., & Cappai, M. G. (2022). Industry 4.0 and precision livestock farming (PLF): an up to date overview across animal productions. *Sensors*, *22*(12), 4319.

[70] Neethirajan, S. (2017). Recent advances in wearable sensors for animal health management. *Sensing and Bio-Sensing Research*, *12*, 15-29.

[71] Neethirajan, S. (2020). Transforming the adaptation physiology of farm animals through sensors. *Animals*, *10*(9), 1512.

[72] Neethirajan, S., & Kemp, B. (2021). Digital livestock farming. *Sensing and Bio-Sensing Research*, *32*, 100408.

[73] Pandey, S., Kalwa, U., Kong, T., Guo, B., Gauger, P. C., Peters, D. J., & Yoon, K. J. (2021). Behavioral monitoring tool for pig farmers: Ear tag sensors, machine intelligence, and technology adoption roadmap. *Animals*, *11*(9), 2665.

[74] Parwekar, P. (2011, September). From internet of things towards CoT. In *2011 2nd international conference on computer and communication technology (ICCCT-2011)* (pp. 329-333). IEEE.

[75] Rao, B. P., Saluia, P., Sharma, N., Mittal, A., & Sharma, S. V. (2012, December). Cloud computing for Internet of Things & sensing based applications. In *2012 Sixth International Conference on Sensing Technology (ICST)* (pp. 374-380). IEEE.

[76] Rao, S. K., & Prasad, R. (2018). Impact of 5G technologies on smart city implementation. *Wireless Personal Communications*, *100*, 161-176.

[77] Reid, E. (2015). The use of implantable microchips for body temperature collection in cattle.

[78] Rodríguez-Prieto, V., Vicente-Rubiano, M., Sánchez-Matamoros, A., Rubio-Guerri, C., Melero, M., Martínez-López, B., ... & Sánchez-Vizcaíno, J. M. (2015). Systematic review of surveillance systems and methods for early detection of exotic, new and re-emerging diseases in animal populations. *Epidemiology & Infection*, *143*(10), 2018-2042.

[79] Shafi, U., Mumtaz, R., Hassan, S. A., Zaidi, S. A. R., Akhtar, A., & Malik, M. M. (2020). Crop health monitoring using iot-enabled precision agriculture. In *IoT Architectures, Models, and Platforms for Smart City Applications* (pp. 134-154). IGI Global.

[80] Silva, B. N., Khan, M., Jung, C., Seo, J., Muhammad, D., Han, J., ... & Han, K. (2018). Urban planning and smart city decision management empowered by real-time data processing using big data analytics. *Sensors*, *18*(9), 2994.

[81] Singh, N., Raza, M., Paranthaman, V. V., Awais, M., Khalid, M., & Javed, E. (2021). Internet of Things and cloud computing. In *Digital Health* (pp. 151-162). Academic Press.

[82] Tedeschi, L. O., Greenwood, P. L., & Halachmi, I. (2021). Advancements in sensor technology and decision support intelligent tools to assist smart livestock farming. *Journal of Animal Science*, *99*(2), skab038.

[83] Verma, P., & Sood, S. K. (2018). Cloud-centric IoT based disease diagnosis healthcare framework. *Journal of Parallel and Distributed Computing*, *116*, 27-38.

[84] Vigneswari, T. (2021). Smart IoT cloud based livestock monitoring system: A survey. *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*, *12*(10), 3308-3315.

[85] Zanella, A., Bui, N., Castellani, A., Vangelista, L., & Zorzi, M. (2014). Internet of things for smart cities. *IEEE Internet of Things journal*, *1*(1), 22-32.

[86] Al-Tamimi, H. J., Al-Dawood, A., & Mahasneh, Z. (2019). The Wolff–Chaikoff effect ameliorates heat stress in rats. *Animal Biotelemetry*, *7*, 1-7.

[87] Alonso, R. S., Sittón-Candanedo, I., García, Ó., Prieto, J., & Rodríguez-González, S. (2020). An intelligent Edge-IoT platform for monitoring livestock and crops in a dairy farming scenario. *Ad Hoc Networks*, *98*, 102047.

[88] Manteuffel C. Parturition detection in sows as test case for measuring activity behaviour in farm animals by means of radar sensors. *Biosyst. Eng.* 2019;184:200–206. doi: 10.1016/j.biosystemseng.2019.06.018.

[89]Arai S., Okada H., Sawada H., Takahashi Y., Kimura K., Itoh T. Evaluation of ruminal motility in cattle by a bolus-type wireless sensor. *J. Vet. Med. Sci.* 2019;19:1–18. doi: 10.1292/jvms.19-0487.

[90]Pampori, Z., & Sheikh, A. (2023). Technology driven livestock farming for food security and

sustainability. *Environment Conservation Journal*, *24*(4), 355-366.
[91].World Health Organization
[92].Neethirajan, S. Recent advances in wearable sensors for animal health management. Sens. Bio-Sens. Res. 2017, 12, 15–29.
[93]. Jorquera-Chavez, M.; Fuentes, S.; Dunshea, F.R.; Jongman, E.C.; Warner, R.D. Computer vision and remote sensing to assess physiological responses of cattle to pre-slaughter stress, and its impact on beef quality: A review. Meat Sci. 2019, 156, 11–22.
[94]. Benaissa, S.; Tuyttens, F.A.; Plets, D.; Cattrysse, H.; Martens, L.; Vandaele, L.; Joseph, W.; Sonck, B. Classification of ingestive-related cow behaviours using RumiWatch halter and neck-mounted accelerometers. Comput. Electron. Agric. 2020, 168, 105153.
[95]. Rayas-Amor, A.A.; Morales-Almaráz, E.; Licona-Velázquez, G.; Vieyra-Alberto, R.; García-Martínez, A.; Martínez-García, C.G.; Cruz-Monterrosa, R.G.; Miranda-de la Lama, G.C. Triaxial accelerometers for recording grazing and ruminating time in dairy cows: An alternative to visual observations. J. Vet. Behav. 2017, 20, 102–108.
[96]. Schaefer, A.L.; Cook, N.J.; Bench, C.; Chabot, J.B.; Colyn, J.; Liu, T.; Okine, E.K.; Stewart, M.; Webster, J.R. The non-invasive and automated detection of bovine respiratory disease onset in receiver calves using infrared thermography. Res. Vet. Sci. 2012, 93, 928–935
[97]. González, L.A.; Bishop-Hurley, G.J.; Handcock, R.N.; Crossman, C. Behavioral classification of data from collars containing motion sensors in grazing cattle. Comput. Electron. Agric. 2015, 110, 91–102.
[98]. Barker, Z.E.; Diosdado, J.A.V.; Codling, E.A.; Bell, N.J.; Hodges, H.R.; Croft, D.P.; Amory, J.R. Use of novel sensors combining local positioning and acceleration to measure feeding behavior differences associated with lameness in dairy cattle. J. Dairy Sci. 2018, 101, 6310–6321.
[99]. ecciolini, V.; Ponzetta, M. Inferring behaviour of grazing livestock: Opportunities from GPS telemetry and activity sensors applied to animal husbandry. Eng. Rural Dev. 2018, 17, 192–198
[100]. Zehner, N.; Umstätter, C.; Niederhauser, J.J.; Schick, M. System specification and validation of a noseband pressure sensor for measurement of ruminating and eating behavior in stable-fed cows. Comput. Electron. Agric. 2017, 136, 31–41.
[101]. Strutzke, S.; Fiske, D.; Hoffmann, G.; Ammon, C.; Heuwieser, W.; Amon, T. Technical note: Development of a noninvasive respiration rate sensor for cattle. J. Dairy Sci. 2019, 102, 690–695.
[102]. Williams, L.R.; Moore, S.T.; Bishop-Hurley, G.J.; Swain, D.L. A sensor-based solution to monitor grazing cattle drinking behaviour and water intake. Comput. Electron. Agric. 2020, 168, 105141.
[103]. Miwa, M.; Oishi, K.; Nakagawa, Y.; Maeno, H.; Anzai, H.; Kumagai, H.; Okano, K.; Tobioka, H.; Hirooka, H. Application of overall dynamic body acceleration as a proxy for estimating the energy expenditure of grazing farm animals: Relationship with heart rate. PLoS ONE 2015, 10, e0128042.
[104]. Meijer, E.; Bertholle, C.; Oosterlinck, M.; Staay, F.; Back, W.; Nes, A. Pressure mat analysis of the longitudinal development of pig locomotion in growing pigs after weaning. BMC Vet. Res. 2014, 10, 37.
[105]. Maselyne, J.; Saeys, W.; Van Nuffel, A. Review: Quantifying animal feeding behaviour with a focus on pigs. Physiol. Behav. 2015, 138, 37–51.
[106]. Matheson, S.M.; Thompson, R.J.; Walling, G.A.; Plötz, T.; Kyriazakis, I.; Edwards, S.A. Relationship between Sow Conformation, Farrowing Floor Type and Posture Change Characteristics Using Accelerometer Data; Newcastle University: Newcastle, UK, 2016.
[107]. Shen, P.-N.; Lei, P.-K.; Liu, Y.-C.; Haung, Y.-J.; Lin, J.-L. Development of a temperature measurement system for a broiler flock with thermal imaging. Eng. Agric. Environ. Food 2016, 9, 291–295
[108]. Mcloughlin, M.P.; Stewart, R.; McElligott, A.G. Automated bioacoustics: Methods in ecology and conservation and their potential for animal welfare monitoring. J. R. Soc. Interface. 2019, 16, 1–12.
[109]. Murillo, A.C.; Abdoli, A.; Blatchford, R.A.; Keogh, E.J.; Gerry, A.C. Parasitic mites alter chicken behaviour and negatively impact animal welfare. Sci. Rep. 2020, 10, 1–12
[110]. Abudabos, A.M.; Samara, E.M.; Hussein, E.O.S.; Al-Ghadi, M.A.; Al-Atiyat, R.M. Impacts of stocking density on the performance and welfare of broiler chickens. Ital. J. Anim. Sci. 2013, 12, e11.
[111]. Saeed, M., Abbas, M. Alagawanyd, A. A. Kamboh, M E. Abd El-Hack, A. F. Khafaga, S. Chao. 2019. Heat Stress Management in Poultry Farms: A comprehensive overview. Journal of Thermal Biology, 84: 414-425.
[112]. Abbas, G., M. Arshad, A. J.Tanveer, M. A. Jabbar, M. Arshad, D. K. A. AL-Taey, A. Mahmood, M. A. Khan, A. A. Khan, Y. Konca, Z. Sultan, R.

A. M. Qureshi, A. Iqbal, F. Amad, M. Ashraf, M. Asif1, R. Mahmood, H. Abbas, S. G. Mohyuddin, M. Y. Jiang. 2022. Combating heat stress in laying hens a review. Pakistan J. Sci. 73 4 : 633-655.

[113]. Chodkowska KA, Wódz K, Wojciechowski J. 2022. Sustainable future protein foods: the challenges and the future of cultivated meat. Foods 11(24):4008 DOI 10.3390/foods11244008.

[114]. Ferrari L, Panaite S-A, Bertazzo A, Visioli F. 2022. Animal-and plant-based protein sources: ascoping review of human health outcomes and environmental impact. Nutrients 14(23):5115DOI 10.3390/nu14235115.

[115]. Istiak MS, Khaliduzzaman A. 2022. Poultry and egg production: an overview. In:Khaliduzzaman A, ed. Informatics in Poultry Production. Singapore: Springer, 3–12.

[116]. Hafez HM, Attia YA. 2020. Challenges to the poultry industry: current perspectives and strategic future after the COVID-19 outbreak. Frontiers in Veterinary Science 7:516DOI 10.3389/fvets.2020.00516.

[117]. Curtin RR, Daley W, Anderson DV. 2014. Classifying broiler chicken condition using audio data.In: 2014 IEEE Global Conference on Signal and Information Processing (GlobalSIP). Piscataway:IEEE, 1141–1144.

[118]. Raghudathesh G, Deepak D, Prasad GK, Arun A, Balekai R, Yatnalli VC, Lata S, Kumar BS.2017. IoT based intelligent poultry management system using Linux embedded system. In: 2017 International Conference on Advances in Computing, Communications and Informatics (ICACCI). Piscataway: IEEE, 449–454.

[119]. Lashari MH, Memon AA, Shah SAA, Nenwani K, Shafqat F. 2018. IoT based poultry environment monitoring system. In: 2018 IEEE International Conference on Internet of Things and Intelligence System (IOTAIS), 1–5.

[120]. Bolfe ÉL, Jorge LAC, Sanches ID, Luchiari Júnior A, da Costa CC, Victoria DC, Inamasu RY,Grego CR, Ferreira VR, Ramirez AR. 2020. Precision and digital agriculture: adoption of technologies and perception of brazilian farmers. Agriculture 10(12)653.

[121]. Wijerathna-Yapa A, Pathirana R. 2022. Sustainable agro-food systems for addressing climate change and food security. Agriculture 12(10):1554 DOI 10.3390/agriculture12101554.

[122]. Arhipova I, Vitols G, Paura L, Jankovska L. 2021. Smart platform designed to improve poultry productivity and reduce greenhouse gas emissions. In: Proceedings of Sixth International Congress on Information and Communication Technology: ICICT 2021. Vol. 1. Cham: Springer,35–46.

[123]. Gebregeziabhear E, Ameha N. 2015. The effect of stress on productivity of animals: a review.Journal of Biology, Agriculture and Healthcare 5(15):14–22.

[124] Naseem S, King AJ. 2018. Ammonia production in poultry houses can affect health of humans,birds, and the environment—techniques for its reduction during poultry production.Environmental Science and Pollution Research 25(16):15269–15293

[125]. Abbas, G., S. Mahmood, F. Ahmad, M. Yousaf, A. Iqbal, M. I. Saleem, A. Manfooz and M. K. Shahzad. 2014. Effects of varying light intensities on immunity level, dressed weight, minor body parts weight, fat deposition, and serum glucose level in broilers. Scholar's Advances in Animal and Veterinary Research, 1(1): 38-42.

[126]. Sousa F, Tinôco I, Paula M, Silva A, Souza C, Batista F, Barbari M. 2016. Medidas para minimizar a emissão de amônia na produção de frangos de corte: revisão/actions to minimize ammonia emission in broiler production. Revista Brasileira de Engenharia de Biossistemas 10(1):51–61 DOI 10.18011/bioeng2016v10n1p51-61.

[127]. Huang J, Gao H, Wan S, Chen Y. 2023. AoI-aware energy control and computation offloading for industrial IoT. Future Generation Computer Systems 139:29–37

[128]. Alizadehsani Z, Gomez EG, Ghaemi H, González SR, Jordan J, Fernández A, Pérez-Lancho B.2022. Modern integrated development environment (IDEs). In: Sustainable Smart Cities and Territories. Cham: Springer, 274–288.

[129]. Liiv I. 2021. Exploration with structured query language. In: Data Science Techniques for Cryptocurrency Blockchains. Behaviormetrics: Quantitative Approaches to Human Behavior, Vol.9. Singapore: Springer DOI 10.1007/978-981-16-2418-6_2.

[129a]. Krogh JW. 2020. MySQL 8 query performance tuning: a systematic method for improving execution speeds. New York: Apress.

[130]. Murugeswari R, Jegadeesh P, Kumar GN, Babu SN, Samar B. 2023. Revolutionizing poultry farming with IoT: an automated management system. In: 2023 4th International Conference on Signal Processing and Communication (ICSPC). Piscataway: IEEE, 22–27.

[131]. Castro F, Chai L, Arango J, Owens C, Smith P, Reichelt S, DuBois C, Menconi A. 2023. Poultry industry paradigms: connecting the dots. Journal

of Applied Poultry Research 32(1):100310DOI 10.1016/j.japr.2022.100310.

[132]. Mazunga F, Mzikamwi T, Mazunga G, Mashasha M, Mazheke V. 2023. IoT based remote poultry monitoring systems for improving food security and nutrition: recent trends and issues. Journal of Agriculture, Science and Technology 22(2):4–21 DOI 10.4314/jagst.v22i2.2.

[133]. Karim S, Rahu MA, Ahmed A, Mirani AA, Jatoi GM. 2018. Energy harvesting for water quality monitoring using floating sensor networks: a generic framework. Sukkur IBA Journal of Emerging Technologies 1(2):19–32 DOI 10.30537/sjet.v1i2.193.

[134]. Saleeva I, Sklyar A, Marinchenko T, Postnova M, Ivanov A. 2020. Efficiency of poultry house heating and ventilation upgrading. In: IOP Conference Series: Earth and Environmental Science.Vol. 433. IOP Publishing, 012041.

[135]. Chung JH. 2021. Carbon dioxide generation by fungal mycelium during spawn run. PhD thesis.The University of Arizona.

[136]. Ibrahim AA. 2018. Carbon dioxide and carbon monoxide level detector. In: 2018 21st International Conference of Computer and Information Technology (ICCIT). Piscataway: IEEE, 1–5.

[137]. Da Costa, T. P., Gillespie, J., Cama-Moncunill, X., Ward, S., Condell, J., Ramanathan, R., & Murphy, F. (2022). A systematic review of real-time monitoring technologies and its potential application to reduce food loss and waste: Key elements of food supply chains and IoT technologies. Sustainability, 15(1), 614.

[138]. Pal, A., & Kant, K. (2020). perishable food, communication, and control in perishable food supply chain. ACM transactions on sensor networks (TOSN), 16(1), 1-41.

[139]. Kayikci, Y., Demir, S., Mangla, S. K., Subramanian, N., & Koc, B. (2022). Data-driven optimal dynamic pricing strategy for reducing perishable food waste at retailers. Journal of cleaner production, 344, 131068.

[139a]. Almalki, F. A., Soufiene, B. O., Alsamhi, S. H., & Sakli, H. (2021). A low-cost platform for environmental smart farming monitoring system based on IoT and UAVs. Sustainability, 13(11), 5908.

[140]. Chhetri, K. B. (2023). Applications of Artificial Intelligence and Machine Learning in Food Quality Control and Safety Assessment. Food Engineering Reviews, 1-21.

[141]. Zhang, M. (2023). Consumer behavior analysis based on Internet of Things platform and the development of precision marketing strategy for fresh food e-commerce. PeerJ Computer Science, 9, e1531.

[142]. Bhattacharya, D., Veeraiah, V., Praveenkumar, S., Prasad, S., John, J., Kumar, B. S., & Gupta, A. (2024). Role of IoT based Kitchen Automation System in Real World. International Journal of Intelligent Systems and Applications in Engineering, 12(10s), 217-225.

[143]. Bouzembrak, Y., Klüche, M., Gavai, A., & Marvin, H. J. (2019). Internet of Things in food safety: Literature review and a bibliometric analysis. Trends in Food Science & Technology, 94, 54-64.

[144]. Pang, Z., Chen, Q., Han, W., & Zheng, L. (2015). Value-centric design of the internet-of-things solution for food supply chain: Value creation, sensor portfolio and information fusion. Information Systems Frontiers, 17, 289-319.

[145]. Sempionatto, J. R., Montiel, V. R. V., Vargas, E., Teymourian, H., & Wang, J. (2021). Wearable and mobile sensors for personalized nutrition. ACS sensors, 6(5), 1745-1760.

[146]. Grecuccio, J., Giusto, E., Fiori, F., & Rebaudengo, M. (2020). Combining blockchain and iot: Food-chain traceability and beyond. *Energies*, *13*(15), 3820.

[147]. Kabadurmus, O., Kayikci, Y., Demir, S., & Koc, B. (2023). A data-driven decision support system with smart packaging in grocery store supply chains during outbreaks. Socio-Economic Planning Sciences, 85, 101417.

[148]. Sagheer, A., Mohammed, M., Riad, K., & Alhajhoj, M. (2020). A cloud-based IoT platform for precision control of soilless greenhouse cultivation. Sensors, 21(1), 223.

[149]. Kalnoor, G., Kumar, B. S., Shariff, M. I. Y., & Kiruba, S. (2022). A SYSTEMATIC SURVEY ON THE COT FOR SMART AGRICULTURE. Ann. For. Res, 65(1), 3724-3736.

[150]. Aazam, M., P. P. Hung and E. -N. Huh, "Smart gateway based communication for CoT," *2014 IEEE Ninth International Conference on Intelligent Sensors, Sensor Networks and Information Processing (ISSNIP)*, Singapore, 2014, pp. 1-6, doi: 10.1109/ISSNIP.2014.6827673.

[151]. Choukidar, G. A. and N. A. Dawande, (2017)"Smart Poultry Farm Automation and Monitoring System," in International Conference on Computing, Communication, Control and Automation (ICCUBEA), 17-18 Aug. 2017 2017, pp. 1-5, doi:10.1109/ICCUBEA.2017.8463953.

[152]. T. S. Gunawan, M. F. Sabar, H. Nasir, M. Kartiwi, and S. M.A. Motakabber, (2019)"Development of Smart Chicken Poultry Farm using RTOS on

Arduino," in IEEE International Conference on Smart Instrumentation, Measurement and Application (ICSIMA), pp.1-5, doi:10.1109/ ICSIMA47653.2019.9057310.

[153]. M. F. H. Hambali, R. K. Patchmuthu, and A. T. Wan,(2020) "IoT Based Smart Poultry Farm in Brunei," in 8th International Conference on Information and Communication Technology(ICoICT), 24-26 June2020, pp. 1-5,doi: 10.1109/ICoICT49345.2020.9166331.

[154]. D. Kanjilal, D. Singh, R. Reddy, and J. Mathew,(2014)"Smart farm: extending automation to thefarm level," Int. J. Sci.Technol. Res, vol. 3, no. 7, pp. 109-113, 2014.

[155]. V. Kowsalya, P. Manisha, S. Kumar, G. Priyanka, and R.Raj,(2019) "Automation of Poultry Farm using PLC," International Journal of Advanced Science and Engineering Research, vol.4, no. 1, pp. 114-119, 2019.

[156]. Lashari, M. H., A. A. Memon, S. A. A. Shah, K. Nenwani,and F. Shafqat, (2018)"IoT Based Poultry Environment Monitoring System," in IEEEInternational Conference on Internet of Things and Intelligence System (IOTAIS), 1-3 Nov.2018, pp. 1-5, doi: 10.1109/IOTAIS.2018.8600837.

[157]. Murad, M., K. M. Yahya, and G. M. Hassan, "Web based poultry farm monitoring system using wireless sensor network," in Proceedings of the 7th International Conference on Frontiers of Information Technology,2009, pp. 1-5.

[158]. Niimi, A., M. Wada, K. Ito, M. Toda, K. Hatanaka, and O.Konishi,(2008) "Broiler- house environment monitoring system using sensor network and mail delivery system," Artificial Life and Robotics, vol. 13, no. 1, pp. 264-270, 2008.

[159]. Nuyya, O., E. Sergeeva, and A. Khomenko,(2018) "Modeling, simulation and implementation of $\pmb{a}$ low- scale poultry farm control system," in 10th International Congress on Ultra-Modern Telecommunications and Control Systems and Workshops (ICUMT), 5- 9 Nov. 2018, pp.1-5, doi: 10.1109/ICUMT.2018.8631253. Z. H. C. Soh, M. H. Ismail,

[160]. Otthaman, F. H., M. K. Safie, M.A. A. Zukri, and S. A. C. Abdullah, (2019)"Development of automatic chicken feeder using Arduino Uno," in International Conference on Electrical, Electronics and System Engineering (ICEESE), 9-10 Nov. 2017 2017, pp.120-124, doi:10.1109/ICEESE.2017.8298402.

[161]. Chakhai, So-In., S. Poolsanguan, and K. Rujirakul,(2014) "A hybrid mobile environmental and population density management system for smart poultry farms," Computers and Electronics in Agriculture, vol. 109, pp. 287-301.

[162]. Sulieman, N. (2019). The economic prospects of Poultry in Gazastrip," Master Thesis.

[163]. Tjoa, G. W., A. Aribowo, and A. S. Putra, (2019)"Design ofAutomatic Drinking Water Supply System for Poultry Cage,"in 5th International Conference on New mediaStudies(CONMEDIA),9-11oct,2019pp.115-doi:10.1109/CONMEDIA46929.2019.89.

[164]. Veeralakshmi P., Sowmya S., Kannan K.N., Anbu S., Ayyappan G.,(2022),"An efficient and smart IoT based pisciculture for developing countries",AIP Conference Proceedings,Vol.2393.doi:10.1063/5.0074418.

[165]. Thamba Meshach W., Hemajothi S., E A M.A.,(2022),"Smart Affect Recognition System for Real-Time Biometric Surveillance Using Hybrid Features and Multilayered Binary Structured Support Vector Machine",Computer Journal,Vol.65,no.4,pp.897-917.doi:10.1093/comjnl/bxaa125.

[166]. Natraj N.A., Kamatchi Sundari V., Ananthi K., Rathika S., Indira G., Rathish C.R.,(2022),"Security Enhancement of Fog Nodes in IoT Networks Using the IBF Scheme",Lecture Notes in Networks and Systems,Vol.514 LNNS,pp.119-129.doi:10.1007/978-3-031-12413-6_10.

[167]. Vijayan D.S., Rose A.L., Arvindan S., Revathy J., Amuthadevi C.,(2020),"Automation systems in smart buildings: a review",Journal of Ambient Intelligence and Humanized Computing.doi:10.1007/s12652-020-02666-9.

[168] Aung, M. M., & Chang, Y. S. (2014). Traceability in a food supply chain: Safety and quality perspectives. *Food Control*, 39, 172-184.

[169] Badia-Melis, R., Mishra, P., & Ruiz-García, L. (2015). Food traceability: New trends and recent advances. *A review*. *Food Control*, 57, 393-401.

[170] Bai, C., Dallasega, P., Orzes, G., & Sarkis, J. (2018). Industry 4.0 technologies assessment: A sustainability perspective. *International Journal of Production Economics*, 229, 107776.

[171] Betz, A., Buchli, J., Göbel, C., & Müller, C. (2015). Food waste in the Swiss food service industry–Magnitude and potential for reduction. *Waste Management*, 35, 218-226.

[172] Galvez, J. F., Mejuto, J. C., & Simal-Gandara, J. (2018). Future challenges on the use of blockchain for food traceability analysis. *Trends in Analytical Chemistry*, 107, 222-232.

[173] Jardine, A. K., Lin, D., & Banjevic, D. (2006). A review on machinery diagnostics and

prognostics implementing condition-based maintenance. *Mechanical Systems and Signal Processing*, 20(7), 1483-1510.

[174] Jedermann, R., Nicometo, M., Uysal, I., & Lang, W. (2014). Reducing food losses by intelligent food logistics. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 372(2017), 20130302.

[175] Kamilaris, A., Kartakoullis, A., & Prenafeta-Boldú, F. X. (2019). A review on the practice of big data analysis in agriculture. *Computers and Electronics in Agriculture*, 143, 23-37.

[176] Lee, J., Bagheri, B., & Kao, H. A. (2014). A cyber-physical systems architecture for industry 4.0-based manufacturing systems. *Manufacturing Letters*, 3, 18-23.

[177] Lim, M. K., Bahr, W., & Leung, S. C. H. (2019). RFID in the warehouse: A literature analysis (1995–2010) of its applications, benefits, challenges and future trends. *International Journal of Production Economics*, 122(1), 395-407.

[178] Manning, L. (2016). Food fraud: Policy and food chain. *Current Opinion in Food Science*, 10, 16-21.

[179] O'Driscoll, E., Daugelaite, J., & Sleator, R. D. (2013). 'Big data', Hadoop and cloud computing in genomics. *Journal of Biomedical Informatics*, 46(5), 774-781.

[180] Papargyropoulou, E., Lozano, R., Steinberger, J. K., Wright, N., & Ujang, Z. B. (2014). The food waste hierarchy as a framework for the management of food surplus and food waste. *Journal of Cleaner Production*, 76, 106-115.

[181] Regattieri, A., Gamberi, M., & Manzini, R. (2007). Traceability of food products: General framework and experimental evidence. *Journal of Food Engineering*, 81(2), 347-356.

[182] Tian, F. (2016). An agri-food supply chain traceability system for China based on RFID & blockchain technology. *13th International Conference on Service Systems and Service Management (ICSSSM)*, 1-6.

[183] Tian, F. (2017). A supply chain traceability system for food safety based on HACCP, blockchain & Internet of things. *Journal of Electrical and Computer Engineering*, 2017, 1-14.

[184] Wolfert, S., Ge, L., Verdouw, C., & Bogaardt, M. J. (2017). Big data in smart farming–A review. *Agricultural Systems*, 153, 69-80.

[185] Yigit, M., Gungor, V. C., & Baktir, A. C. (2014). Cloud computing for smart grid applications. *Computer Networks*, 70, 312-329.

[186] Zhang, C., Ren, J., & Yang, S. (2014). IoT-enabled real-time production performance analysis and decision support. *International Journal of Production Research*, 52(13), 3955-3970.

1. References

[187] Antle, J. M., Jones, J. W., & Rosenzweig, C. (2017). Next generation agricultural system data, models and knowledge products: Introduction. *Agricultural Systems*, 155, 186-190.

[188] Ayars, J. E., Phene, C. J., Hutmacher, R. B., Davis, K. R., Schoneman, R. A., Vail, S. S., & Mead, R. M. (2015). Water use by drip-irrigated late-season peaches. *Agricultural Water Management*, 17(1-3), 37-52.

[189] Balafoutis, A., Beck, B., Fountas, S., Tsiropoulos, Z., Cavalaris, C., Vangeyte, J., ... & van der Wal, T. (2017). Precision agriculture technologies positively contributing to GHG emissions mitigation, farm productivity and economics. *Sustainability*, 9(8), 1339.

[190] Blackmore, S., Godwin, R. J., & Fountas, S. (2003). The analysis of spatial and temporal trends in yield map data over six years. *Biosystems Engineering*, 84(4), 455-466.

[191] Bongiovanni, R., & Lowenberg-DeBoer, J. (2004). Precision agriculture and sustainability. *Precision Agriculture*, 5(4), 359-387.

[192] Ehsani, R., Sullivan, M., Schueller, J. K., & Whitney, J. D. (2009). Evaluating the profitability of an automatic tractor guidance system for citrus grove operations. *Computers and Electronics in Agriculture*, 65(2), 272-279.

[193] Evans, R. G., & Sadler, E. J. (2008). Methods and technologies to improve efficiency of water use. *Water Resources Research*, 44(7), W00E04.

[194] Gebbers, R., & Adamchuk, V. I. (2010). Precision agriculture and food security. *Science*, 327(5967), 828-831.

[195] Grisso, R. D., Alley, M. M., Thomason, W. E., Holshouser, D. L., & Roberson, G. T. (2009). Precision farming tools: Yield monitor. *Virginia Cooperative Extension*, 442-502.

[196] Grisso, R. D., Smith, S., & Pitman, R. (2014). Precision agriculture: NRCS support for emerging technologies. *USDA NRCS*.

[197] Hunt, E. R., Hively, W. D., Fujikawa, S. J., Linden, D. S., Daughtry, C. S. T., & McCarty, G. W. (2010). Acquisition of NIR-green-blue digital photographs from unmanned aircraft for crop monitoring. *Remote Sensing*, 2(1), 290-305.

[198] Jones, J. W., Antle, J. M., Basso, B., Boote, K. J., Conant, R. T., Foster, I., ... & Rosenzweig, C. (2017). Brief history of agricultural systems modeling. *Agricultural Systems*, 155, 240-254.

[199] McBratney, A. B., Whelan, B. M., Ancev, T., & Bouma, J. (2005). Future directions of precision agriculture. *Precision Agriculture*, 6(1), 7-23.

[200] McCown, R. L. (2002). Locating agricultural decision support systems in the troubled past and socio-technical complexity of 'models for management'. *Agricultural Systems*, 74(1), 11-25.

[201] Mulla, D. J. (2013). Twenty five years of remote sensing in precision agriculture: Key advances and remaining knowledge gaps. *Biosystems Engineering*, 114(4), 358-371.

[202] Pierce, F. J., & Nowak, P. (1999). Aspects of precision agriculture. *Advances in Agronomy*, 67, 1-85.

[203] Scharf, P. C., Kitchen, N. R., Sudduth, K. A., Davis, J. G., Hubbard, V. C., & Lory, J. A. (2009). Field-scale variability in optimal nitrogen fertilizer rate for corn. *Agronomy Journal*, 97(2), 452-461.

[204] Stensrud, D. J. (2007). *Parameterization Schemes: Keys to Understanding Numerical Weather Prediction Models*. Cambridge University Press.

[205] Zhang, C., & Kovacs, J. M. (2012). The application of small unmanned aerial systems for precision agriculture: a review. *Precision Agriculture*, 13(6), 693-712.

[206] Zhang, N., Wang, M., & Wang, N. (2002). Precision agriculture—a worldwide overview. *Computers and Electronics in Agriculture*, 36(2-3), 113-132.

[207] Banhazi, T. M., Seedorf, J., Rutley, D. L., & Pitchford, W. S. (2008). Identification of risk factors for sub-optimal housing conditions in Australian piggeries: Part 2. Emission factors and study recommendations. *Journal of Agricultural Safety and Health*, 14(1), 53-69.

[208] Baumont, R., Ingrand, S., & Schmidely, P. (2018). Feeding behaviour of ruminants and precision livestock farming. *Animal Feed Science and Technology*, 250, 63-75.

[209] Bewley, J. M., Grott, M. W., Einstein, M. E., & Schutz, M. M. (2010). Impact of intake water temperatures on reticulorumen temperature and water consumption in lactating dairy cows. *Journal of Dairy Science*, 93(4), 1941-1950.

[210] Briske, D. D., Derner, J. D., Brown, J. R., Fuhlendorf, S. D., Teague, W. R., Havstad, K. M., ... & Willms, W. D. (2011). Rotational grazing on rangelands: Reconciliation of perception and experimental evidence. *Rangeland Ecology & Management*, 64(1), 3-17.

[211] Brown-Brandl, T. M., Eigenberg, R. A., & Nienaber, J. A. (2003). Heat and moisture production of growing-finishing swine. *Transactions of the ASAE*, 46(4), 1133.

[212] Chapinal, N., de Passillé, A. M., Rushen, J., & Wagner, S. (2011). Automated methods for detecting lameness and measuring analgesia in dairy cattle. *Journal of Dairy Science*, 94(10), 5474-5484.

[213] Davidson, R., Schrama, D., & Simmins, P. H. (2017). Precision livestock farming: Drivers and technology applications. *Animal Frontiers*, 7(1), 24-31.

[214] Foddai, A., Rosenbaum Nielsen, L., & Krogh, M. A. (2016). Cost-effectiveness of using pooled milk testing for surveillance of paratuberculosis in Danish dairy herds. *Preventive Veterinary Medicine*, 133, 84-95.

[215] Fricke, P. M., Giordano, J. O., Valenza, A., Lopes, G., Amundson, M. C., & Carvalho, P. D. (2014). Reproductive performance of dairy cows managed with synchronization of ovulation and timed artificial insemination. *Animal Reproduction*, 11(3), 263-271.

[216] Jacobs, J. A., & Siegford, J. M. (2012). Invited review: The impact of automatic milking systems on dairy cow management, behavior, health, and welfare. *Journal of Dairy Science*, 95(5), 2227-2247.

[217] Mishra, A. R., Khurana, A., Khurana, P., & Das, S. (2016). Stress and its impact on farm animal health: A review. *International Journal of Science, Environment and Technology*, 5(4), 2058-2064.

[218] O'Shaughnessy, S. A., Evett, S. R., & Colaizzi, P. D. (2014). Dynamic prescription maps for site-specific variable rate irrigation of cotton. *Agricultural Water Management*, 131, 1-13.

[219] Pérez-Ramírez, E., Bergeron, R., & Gonyou, H. W. (2010). Influence of daily management practices on the welfare of grow-finisher pigs in very large, specialized farms. *Journal of Animal Science*, 88(11), 3705-3715.

[220] Robinson, T. P., Wertheim, H. F. L., Kakkar, M., Kariuki, S., Bu, D., & Price, L. B. (2015). Animal production and antimicrobial resistance in the clinic. *The Lancet*, 387(10014), e1-e3.

[221] Rutten, C. J., Velthuis, A. G. J., Steeneveld, W., & Hogeveen, H. (2013). Invited review: Sensors to support health management on dairy farms. *Journal of Dairy Science*, 96(4), 1928-1952.

[222] Saint-Dizier, M., & Chastant-Maillard, S. (2018). Methods and on-farm devices to predict calving time in cattle. *The Veterinary Journal*, 224, 8-12.

[223] Spelman, R. J., Hayes, B. J., & Berry, D. P. (2007). Use of molecular technologies for the advancement of animal breeding: Genomics, transgenics and epigenetics. *Reproduction, Fertility and Development*, 19(4), 429-440.

[224] Steeneveld, W., Vernooij, J. C., & Hogeveen, H. (2012). Effect of climate on milk production and

fertility in dairy cattle: A systematic review. *Journal of Dairy Science*, 95(4), 1998-2012.

[225] Steeneveld, W., Tauer, L. W., Hogeveen, H., & Oude Lansink, A. G. J. M. (2015). Comparing technical efficiency of farms with an automatic milking system and a conventional milking system. *Journal of Dairy Science*, 98(11), 7249-7257.

[226] VanRaden, P. M. (2008). Efficient methods to compute genomic predictions. *Journal of Dairy Science*, 91(11), 4414-4423.

[227] Amazon. (2023). Amazon Web Services. Retrieved from aws.amazon.com

[228] Microsoft. (2023). Microsoft Azure. Retrieved from azure.microsoft.com

[229] Google. (2023). Google Cloud Platform. Retrieved from cloud.google.com

[230] IBM. (2023). IBM Cloud. Retrieved from ibm.com/cloud

[231] Oracle. (2023). Oracle Cloud. Retrieved from oracle.com/cloud

[232] Atzori, L., Iera, A., & Morabito, G. (2010). The Internet of Things: A survey. *Computer Networks*, 54(15), 2787-2805.

[233] Miorandi, D., Sicari, S., De Pellegrini, F., & Chlamtac, I. (2012). Internet of Things: Vision, applications and research challenges. *Ad Hoc Networks*, 10(7), 1497-1516.

[234] Vermesan, O., & Friess, P. (Eds.). (2013). *Internet of Things: Converging Technologies for Smart Environments and Integrated Ecosystems*. River Publishers.

[235] Zanella, A., Bui, N., Castellani, A., Vangelista, L., & Zorzi, M. (2014). Internet of Things for smart cities. *IEEE Internet of Things Journal*, 1(1), 22-32.