A Model for the Internet of Veterinary Medical Things: Navigating Challenges in the World of Science and Technology

Muhammad Ijaz Khan[1], Mudasir Mahmood[1],Asia Zaman[1], Muhammad Farhan[1], Saba Sana[1], Saadat Ullah[1,]Muhammad Saqib Khan[2]

ijaz171@gmail.com
mudasir@gu.edu.pk
aasiazaman123@gmail.com
muhammadfarhan01@gmail.com
sabasana721@gmail.com
Ksaadat125@gmail.com
saqiblecturer@gmail.com

1. Institute of Computing and Information Technology, Gomal University, Pakistan.
2. Institute of Business Administration, Gomal University, Pakistan.

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Abstract-The rapid evolution of science and technology has brought forth numerous advancements that have significantly transformed various industries, including the field of veterinary medicine. In this study, we introduce a novel model for the Internet of Veterinary Medical Things (IoVMT), which aims to enhance the quality and efficiency of veterinary care by leveraging the power of interconnected devices, sensors, and data analytics. This paper presents an in-depth exploration of the challenges and opportunities presented by the integration of IoVMT in the contemporary world of science and technology.This study introduces a novel model for the Internet of Veterinary Medical Things (IoVMT), designed to enhance veterinary care through interconnected devices, sensors, and data analytics. We explore the challenges and opportunities presented by IoVMT integration in the current scientific and technological landscape.

Keywords:Internet of Veterinary Medical Things, Wearables, Veterinary, Internet of Things

1. INTRODUCTION:

The rapid advancements in science and technology have profoundly impacted various industries, including veterinary medicine, by offering innovative solutions to address complex challenges. One such innovation, the Internet of Things (IoT), has emerged as a powerful tool for connecting various devices, sensors, and data analytics to revolutionize numerous sectors, such as healthcare, agriculture, and transportation [1]. In the context of veterinary medicine, the potential of IoT can be harnessed to create the Internet of Veterinary Medical Things (IoVMT), a groundbreaking approach to improve the quality and efficiency of animal care through seamless communication and data sharing among stakeholders. This research aims to present a detailed overview of a novel model for IoVMT, exploring its potential benefits, challenges, and implications in the contemporary world of science and technology.

The IoVMT model seeks to integrate various components, such as wearable devices for animals, remote monitoring systems, and advanced data analytics, to facilitate real-time monitoring of animal health, early detection of diseases, and tailored treatment plans. By connecting veterinarians, pet owners, researchers, and other stakeholders, the IoVMT model fosters collaboration and data-driven decision-making to improve animal health outcomes and welfare [2]. Furthermore, the model's incorporation of advanced data analytics techniques allows for the extraction of valuable insights from large-scale animal health trends, contributing to the development of more effective and targeted interventions.

However, the implementation of the IoVMT model faces numerous challenges, including data privacy, security, and ethical considerations. As the model relies on the collection, storage, and sharing of sensitive animal health data, ensuring the privacy and security of this information becomes a critical concern. Additionally, ethical issues surrounding the use of wearable devices on animals and the potential for increased surveillance warrant thorough discussion and evaluation.

This research paper is structured as follows: first, we provide a comprehensive overview of the IoVMT model, describing its key components and the technologies involved. Next, we delve into the potential benefits of implementing the model in veterinary medicine, highlighting its transformative potential for animal health and welfare. We then discuss the challenges and barriers to IoVMT implementation, addressing data privacy, security, and ethical concerns. Following this, we present case studies demonstrating the successful application of IoVMT in various veterinary scenarios, showcasing its practical implications and potential for widespread adoption. Finally, we conclude by emphasizing the importance of addressing the challenges associated with the IoVMT model and the need for collaboration among stakeholders to optimize its benefits for animal health and welfare in the ever-evolving world of science and technology.

2. CHALLENGES IN IMPLEMENTATION OF IoVMT:

The implementation of the Internet of Veterinary Medical Things (IoVMT) model presents several challenges that must be addressed to ensure its successful integration and optimization for animal health and welfare. These challenges can be categorized into technological, logistical, and ethical domains.

2.1. TECHNOLOGICAL CHALLENGES:

a) Data Privacy and Security: With the collection, storage, and sharing of sensitive animal health data among various stakeholders, the IoVMT model must prioritize data privacy and security [3]. Ensuring that sensitive information is protected from unauthorized access, breaches, and misuse is critical. This challenge requires the development and implementation of robust encryption and authentication methods, as well as compliance with data protection regulations.

b) Interoperability and Standardization: The IoVMT model involves the integration of numerous devices, sensors, and data analytics tools, which may be developed by different manufacturers and utilize diverse communication protocols. Ensuring seamless interoperability among these components is vital for the model's success. Standardization of data formats and communication protocols, as well as the development of open-source platforms and Application Programming Interfaces (APIs), can help address this challenge [4].

c) Scalability: As the IoVMT model expands to accommodate a growing number of devices and stakeholders, it must be designed to handle increasing data volumes and network traffic. Scalability is crucial to maintain system performance, reliability, and efficiency. This challenge can be addressed through efficient data management techniques, distributed data processing, and cloud-based storage solutions [5].

2.2. LOGISTICAL CHALLENGES:

a) Infrastructure and Connectivity: Implementing the IoVMT model requires the establishment of a reliable infrastructure and connectivity to support the seamless transmission of data among devices and stakeholders. In remote or underdeveloped areas, the lack of sufficient infrastructure and connectivity can pose significant barriers to the adoption of IoVMT [6].

b) Cost and Investment: The development and implementation of the IoVMT model involve considerable investments in devices, sensors, software, and infrastructure. The costs associated with setting up and maintaining the system may be prohibitive for some stakeholders, particularly small veterinary practices, or individual pet owners [7].

2.3. ETHICAL CHALLENGES:

a) Animal Welfare: The use of wearable devices and sensors on animals raises ethical concerns regarding their potential impact on animal welfare. Ensuring that these devices are designed and implemented with animal comfort, safety, and well-being in mind is essential [8].

b) Surveillance and Consent: The IoVMT model may increase surveillance of animals, potentially infringing on their privacy and autonomy. Addressing the ethical implications of such surveillance, as well as obtaining informed consent from pet owners for the collection and use of their animals' data, is crucial [9].

Overcoming these challenges is necessary for the successful implementation of the IoVMT model. Addressing technological, logistical, and ethical concerns requires a collaborative approach among stakeholders, as well as the development of innovative solutions and the establishment of regulatory frameworks that prioritize animal health and welfare [11].

3. PROPOSED MODEL

The proposed model integrates various components to create a comprehensive ecosystem that enables efficient and effective management of animal health in a veterinary context. The model consists of the following components:

1. **Veterinary Medical Professionals (VMP):** These are the veterinarians and other medical professionals responsible for diagnosing, treating, and managing the health of animals/pets/patients. They play a critical role in making informed decisions based on the data and insights provided by the system.
2. **Analyzer and Visualizer (A&V):** This component is responsible for processing the data collected from various sources, such as sensors, trackers, and wearables. It employs advanced data analytics techniques to extract valuable insights and presents them in a user-friendly format through visualization tools, aiding stakeholders in monitoring animal health trends and making data-driven decisions.
3. **Farm Manager (FM):** The farm manager oversees the overall management and operations of a farm or facility, ensuring the well-being of animals and the efficient use of resources. In this model, the farm manager can leverage the data and insights provided by the A&V component to optimize farm operations and improve animal health outcomes.
4. **Animals/Pets/Patients (A/P/P):** These are the primary subjects of the model, whose health and welfare are being monitored and managed through the various components of the system.
5. **IT Officials (IT O):** These are the technology experts responsible for the development, implementation, and maintenance of the hardware and software components of the system, ensuring seamless connectivity, data privacy, and security.
6. **Database (DB):** A secure, centralized database stores the collected data from various sources, such as sensors, trackers, and wearables. The database must be designed with robust data privacy and security measures, ensuring compliance with relevant data protection regulations.
7. **Routers (RA, RB, RC):** These devices facilitate the transmission of data among various components of the system, such as wearable devices, sensors, live cameras, and the central database. Routers ensure reliable connectivity and efficient data transmission across the network.
8. **Live Cameras for Monitoring (LCM):** Live cameras are strategically placed to provide real-time video monitoring of animals, enabling remote observation and early identification of behavioral changes or health issues.

9. **Sensors (S):** Sensors are deployed to collect data on various environmental factors, such as temperature, humidity, air quality, and noise levels, which may impact animal health and behavior.

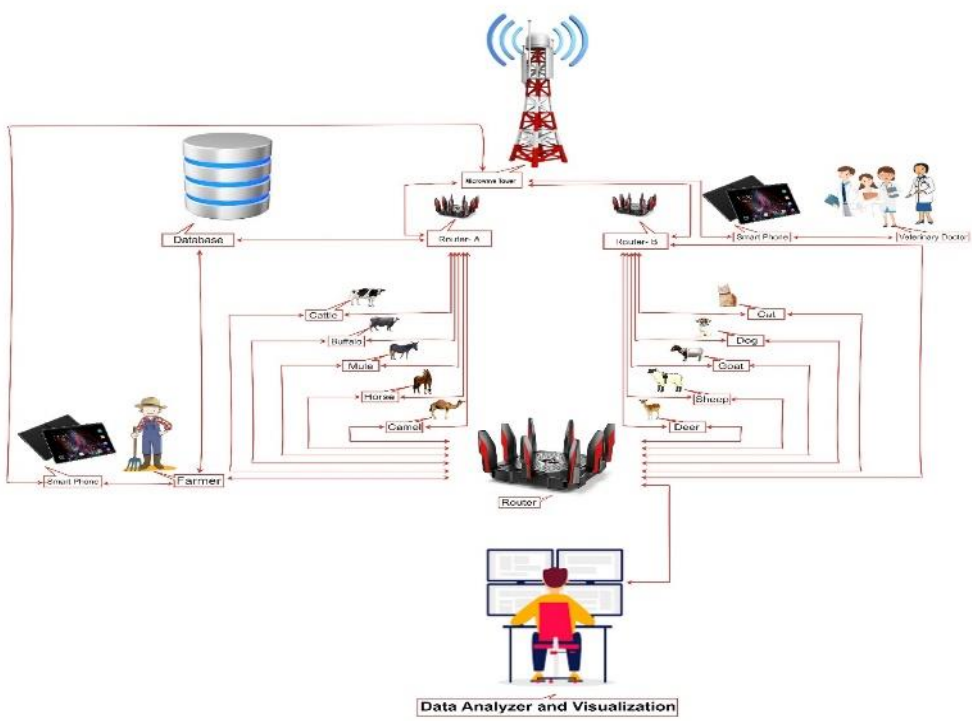
10. **Trackers (T):** Trackers are used to monitor the location and movement of animals, providing valuable data on their activity levels, grazing patterns, or potential health concerns.

11. **Wearables (W):** Wearable devices, such as smart collars or harnesses, collect real-time data on animal health indicators, including heart rate, temperature, respiration rate, and activity levels.

12. **Smart Phone (SP):** Smartphones serve as an interface for stakeholders, such as veterinarians, farm managers, and pet owners, to access the data and insights provided by the A&V component, enabling remote monitoring and management of animal health.

13. **Microwave Tower (MT):** The microwave tower is responsible for providing wireless connectivity to the various components of the system, ensuring reliable data transmission and communication among stakeholders.

This comprehensive model leverages the power of interconnected devices, data analytics, and communication technologies to enhance the quality and efficiency of veterinary care. By addressing the challenges associated with the implementation of this model, such as data privacy, security, and ethical concerns, it holds the potential to significantly improve animal health outcomes and contribute to a more sustainable future. The following diagram



4. INTERACTION OF VARIOUS COMPONENTS OF THE MODEL:

In the proposed model, the various components interact with each other to create a seamless ecosystem that enables efficient and effective management of animal health. The interactions among components is described as follows:

1. The Analyzer and Visualizer (A&V) communicates with Veterinary Medical Professionals (VMP) to provide reporting, treatment guidelines, and updates on the health of Animals/Pets/Patients (A/P/P) via the internet through Routers (RC, RB), the Microwave Tower (MT), and Smart Phones (SP).

2. A&V is also connected to the Farm Manager (FM) for similar reporting and updates related to A/P/P, using intranet connections via Router (RC).

3. A&V connects with A/P/P, which are equipped with Trackers (T), Sensors (S), and Wearables (W) for monitoring and analyzing data through Routers (RC, RB).
4. A&V accesses the Database (DB) with the permission and authority of FM via Router (RC).
5. VMPs connect with A&V through the internet via Smart Phones (SP), the Microwave Tower (MT), and Routers (RB, RC).
6. VMPs can also connect with A/P/P equipped with Trackers (T), Sensors (S), and Wearables (W) via Smart Phones (SP), the Microwave Tower (MT), and Routers (RA, RB) for research and treatment purposes. However, VMPs do not have direct access to DB in order to maintain data privacy and security.
7. VMPs communicate with FM for treatment updates and reports on A/P/P via Smart Phones (SP), the Microwave Tower (MT), and FM's Smart Phone (SP).
8. A/P/P are equipped with Trackers (T), Sensors (S), and Wearables (W) that feature built-in cameras, which are connected to VMPs via Routers (RA, RB), the Microwave Tower (MT), and Smart Phones (SP).
9. A/P/P are monitored and analyzed by A&V via intranet through Routers (RA, RB, RC).
10. FM has access to all components of this model: FM connects with VMPs via Smart Phones (SP), the Microwave Tower (MT), and their own Smart Phone (SP); with A/P/P and Trackers (T), Sensors (S), and Wearables (W) through Routers (RC, RB), and the Database (DB); and directly with A&V via intranet through Router (RC).
11. The Database (DB) securely stores all data and is only directly accessible by FM. With FM's authorization, A&V and VMPs can access the DB for further proceedings. Meanwhile, they have direct access to A/P/P through Trackers (T), Sensors (S), and Wearables (W).

The model establishes a robust network of interconnected components, facilitating secure and efficient communication, data acquisition, analysis, and decision-making in the field of veterinary medicine.

The following figure represents the interaction of various components of the model.

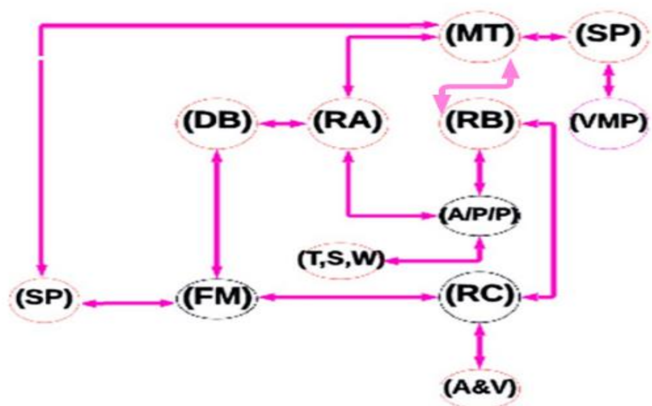


Fig 2: Interaction of various components of the model

5. EXPLANATION OF COMPONENT

Various components of the model are described as under:

- **Veterinary Medical Professionals (VMP):** Veterinary Medical Professionals primarily perform online assessments of animals' health, diagnose problems, and provide treatment recommendations. They offer online instructions for animal wound care and dressings, conduct online surgeries, administer vaccinations, and operate medical equipment such as X-rays and ultrasounds. VMPs also provide online advice to Farm Managers about general care, medical conditions, and treatments, prescribe medication, and perform euthanasia when necessary. They utilize a variety of online medical devices, including wearables, X-rays, and ultrasounds, to treat animals and address their healthcare needs.
- **Analyzer and Visualizer (A&V):** IoT has significantly impacted livestock monitoring. The Analyzer and Visualizer handles the data processing and analysis that helps prevent losses. Most animal healthcare monitoring systems employ wearables that communicate data to Analyzers and Visualizers using low-bandwidth communication technologies. By monitoring vital indicators such as blood pressure, heart rate, and respiration rate using wearables, Veterinary Medical Professionals can detect and address potential health issues in animals.
- **Farm Manager (FM**): For farmers, time is money, and traditional farm data recording can be a cumbersome and time-consuming task. Farm Managers work closely with animals, Veterinary Medical Professionals, and Analyzers and Visualizers to ensure the health and well-being of their livestock.
- **Animals/Pets/Patients (A/P/P):** The primary goal of this model is to maintain and improve the health of Animals/Pets/Patients. Animals are equipped with sensors, trackers, wearables, and cameras for monitoring purposes, enabling healthcare interventions and productivity enhancements through data-driven research.
- **IT Officials (IT O):** IT Officials are responsible for installing, upgrading, and maintaining the Internet of Veterinary Medical Things (IoVMT) system. They address any errors or issues and work to improve the functionality of the devices.
- **DataBase (DB):** The DataBase stores data collected from various trackers, sensors, and wearables with built-in cameras. Access to the DataBase is limited for security purposes and to protect sensitive information.
- **Routers (RA), (RB), (RC):** Routers facilitate connectivity and data routing among different components within the Internet of Veterinary Medical Things (IoVMT) system.
- **Live Cameras for Monitoring (LCM):** Live cameras, in conjunction with various advanced sensors, trackers, and wearables, monitor the position, behavior, and signs of illness or disease in animals and pets. These cameras provide real-time data, enabling prompt interventions and adjustments to animal care as needed.
- **Trackers, Sensors, and Wearables (T, S, W):** Trackers, sensors, and wearables are essential tools for monitoring and protecting animals. Historically, human curiosity and passion drove animal tracking research. Modern technology now allows for continuous analysis of animal populations using both long-term and short-term data. Tracking devices, often equipped with acceleration sensors, can accurately determine the location and movement of animals.

The adoption of cutting-edge technology that considers animal behavior leads to the development of novel animal welfare applications and scientific research. The central concept behind recent innovations in network design is smart systems inspired by specific animal behaviors.

Wild animals can also be monitored using wearable and non-wearable sensor devices. Innovative hybrid architectures employ short-range, ad hoc networks in breeding and nesting areas, as well as global cellular networks during long migrations, such as the 4,000 km annual journey of the endangered whooping crane [8]. This approach gives rise to novel cellular sensor networks tailored to specific monitoring needs.

6. FEATURES OF LIVESTOCK TRACKING DEVICES

Livestock tracking devices have become increasingly important for farmers, researchers, and conservationists to monitor and manage the health, safety, and well-being of their animals. These devices come with various features that aid in tracking and monitoring animals, ensuring their safety, and providing valuable data for analysis. Below is a table summarizing the key features of livestock tracking devices:

Table 1: Features of Livestock Tracking Devices

S. No.	Livestock Tracking Device Feature	Description
1	Global Connectivity	Asset tracking options include cellular (2G, 4G LTE-M/NB-IoT), LoRaWAN®, Sigfox, and Bluetooth® technologies.
2	Rugged & Weatherproof	Livestock monitoring equipment and animal GPS collars are protected by IP68-rated housing to endure challenging conditions, impact, fine dust, and brief submersion.
3	Batteries	Store-bought batteries are used to power GPS animal tracker devices, and battery life is monitored for "battery low" and "battery critical" alarms.
4	Off the Shelf Batteries	GPS animal tracker devices can be powered by store-bought batteries, simplifying replacements and maintenance.
5	Periodic or Movement-Based	Adaptive smart livestock monitoring technology allows you to receive location updates frequently throughout the day or only when movement is detected.
6	Theft Recovery	In the event of theft or loss, switch to recovery mode using animal monitoring technology to enable near-live tracking for livestock recovery.
7	Sleep Mode	To conserve battery life and optimize data consumption, stationary cow monitoring devices can go into sleep mode, which reduces the update frequency to only once daily until movement occurs.
8	Advanced Geofencing	Create personalized geofences and notifications for when livestock enters or exits certain areas. Additionally, geofences can be quickly downloaded to a smartphone for improved location-based actions with a thorough GPS livestock monitoring system.
9	Inactivity Detection	Set alerts for when cattle stop moving for a predetermined period of time on collar GPS trackers.
10	Easy Install	There are various ways to attach devices to animals using GPS collars or to livestock equipment using screws, bolts, cable ties, rivets, and other methods.
11	Manufacturer's Warranty	Livestock tracking devices come with a two-year manufacturer's warranty.
12	Flexible Configuration	Configure device parameters, including heart rate, movement, and accelerometer settings, to suit any application requiring an animal tracking system.

7. BENEFITS OF ANIMAL HEALTHCARE MANAGEMENT VIA IoVMT:

- Remote Monitoring: IoVMT enables real-time remote monitoring of animals, making it easier for veterinary professionals and farm managers to keep an eye on their health and well-being without having to be physically present at all times.
- Early Disease Detection: With the help of sensors, trackers, and wearables, IoVMT can identify early signs of illness or injury, allowing for prompt intervention and treatment, which can reduce the severity of the disease and improve recovery rates.
- Improved Animal Welfare: Continuous monitoring of animals' vital signs, behavior, and movement ensures that their welfare is prioritized, enabling prompt action in cases of distress, injury, or illness.
- Enhanced Productivity: By closely monitoring animals' health, farm managers can make informed decisions about their management, leading to increased productivity and overall performance.
- Data-Driven Decision Making: IoVMT generates a wealth of data that can be analyzed to provide valuable insights into animal health trends, enabling more informed decision-making for the betterment of the animals and the industry as a whole.
- Cost Savings: Early detection and treatment of health issues can lead to reduced veterinary expenses and improved animal health, resulting in cost savings for farm managers and animal owners.
- Reduced Labor Requirements: With remote monitoring and automated data collection, IoVMT can help reduce the need for manual labor, allowing farm managers to allocate resources more effectively.
- Improved Research Capabilities: IoVMT provides a rich source of data for researchers, enabling them to study animal behavior, health patterns, and treatment efficacy in greater depth and detail, ultimately leading to advancements in animal healthcare and management.
- Enhanced Biosecurity: By monitoring animal health and movement, IoVMT can help identify and control potential disease outbreaks, ensuring the safety and well-being of the animals and their caretakers.
- Eco-friendly Practices: IoVMT can contribute to more sustainable farming practices by optimizing resource utilization, reducing waste, and promoting animal welfare, which in turn can have positive effects on the environment.

The adoption of IoVMT in animal healthcare management offers numerous benefits, ranging from improved animal welfare and productivity to cost savings and eco-friendly practices. This technology holds significant potential to revolutionize the way we care for and manage animals in various settings, including farms, veterinary clinics, and research facilities.

8. FUTURE WORK

The research presented in this study has focused on developing a model for the IoVMT in the context of modern science and technology challenges. This model has shown great potential in revolutionizing animal healthcare management by providing real-time monitoring, early disease detection, and data-driven decision-making.In future work, the proposed IoVMT model can be further enhanced by integrating advanced technologies such as artificial intelligence, machine learning, and big data analytics for more accurate predictions and decision-making. The development of more sophisticated sensors and wearables, as well as the focus on enhanced data security and privacy, will also play a crucial role. Additionally, efforts should be made to ensure interoperability and standardization, along with the creation of user-friendly interfaces and systems. Extending the applicability of the IoVMT model to various animal species and diverse environments, including zoos, wildlife reserves, and companion animal care, will broaden its impact and potential benefits. Continual research and development in this field will pave the way for more advanced and effective animal healthcare management solutions.

9. CONCLUSION

In conclusion, the proposed IoVMT model holds significant promise for transforming the way we care for and manage animals in various settings, including farms, veterinary clinics, and research facilities. By addressing modern science and technology challenges, this model can contribute to improved animal welfare, enhanced productivity, cost savings, and eco-friendly practices. Continued research and development in this field will pave the way for more advanced and effective animal healthcare management solutions, ultimately benefiting both the animals and the people who care for them.

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