Meta-Verse Assisted Healthcare Body Sensor Network Architecture

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***Abstract*—These days, the usage of body area network enabled healthcare services has been increasing widely in practice. The objective is to monitor healthcare in real time from different remote services. However, the existing body area network architecture for healthcare services is not sufficient and optimal. In this paper, we present a Meta-Verse-based Healthcare Body Sensor Network Architecture to offer seamless healthcare services to different subjects. The architecture consisted of metaverse technology, healthcare sensors, and fog nodes to offer seamless services to the subjects. In architecture, we consider the heterogeneous devices such as medical sensors (e.g., heart rate, oxygen, blood pressure, and temperature) to be connected with the mobile devices and metaverse fog nodes to process the healthcare application tasks of subjects. This paper presents the meta verse body area network offloading scheduling (MBANOS) based on a convolutional neural network (CNN) for all healthcare sensor data and their tasks. Simulation results show that MBANOS outperformed and obtained the highest score of data processing on different nodes to maintain the subject healthcare in practice.**

***Index Terms*—Body Area Network, Healthcare, CNN, Architecture, Scheduling, Offloading.**

I. Introduction

Integrating the metaverse with healthcare body sensor networks (BSNs) ushers in a novel age in medical care, augmenting patient surveillance, diagnosis, therapy, and recovery. By harnessing the immersive and interactive features of the metaverse, BSNs can offer real-time data analysis, customized medication, and enhanced patient results within a comprehensive and integrated healthcare system. BSNs consist of wearable or implantable devices that constantly monitor physiological indicators such as heart rate, blood pressure, and glucose levels. The sensors gather and transmit data to a central system for analysis, enabling ongoing health monitoring and prompt medical actions [1], [2].

The Metaverse Body Area Network (BAN) in healthcare is a cutting-edge combination of complex virtual environments and wearable health monitoring technologies. This entails the fusion of enhanced physical reality with persistent virtual environments, encompassing augmented reality (AR), virtual reality (VR), and mixed reality (MR). The BAN system comprises wearable computer equipment and sensors positioned on or close to the human body to monitor health conditions and vital indicators constantly [3], [4], [5].

This connection facilitates instantaneous surveillance via devices such as smartwatches and medical implants within the healthcare sector. These devices gather data on vital metrics such as heart rate, blood pressure, and glucose levels. Virtual healthcare environments facilitate patient-provider interactions for consultations, diagnostics, and treatment planning, hence enhancing the accessibility of healthcare services. Telemedicine is improved by the use of virtual reality (VR) environments, which allow clinicians to remotely evaluate patients by accessing real-time data via body area networks (BANs) [6], [7], [8], [9].

Examples of applications include virtual reality-based physiotherapy programs, ongoing surveillance and quick interventions for managing chronic diseases, and remote surgery made easier by instant feedback from body area networks. The technological advantages include the smooth integration of data into electronic health records (EHRs), customized healthcare experiences, and enhanced patient-provider contact in virtual environments [10].

The obstacles encompass the imperative to safeguard the confidentiality and integrity of health data, uphold the precision and dependability of wearable device data, and construct the requisite technical infrastructure. Future predictions indicate continuous progress in wearable technology, increased utilization of Metaverse technologies for accessible healthcare, and the establishment of regulatory frameworks to tackle ethical, legal, and societal concerns. Integrating the metaverse and Body Area Network (BAN) in healthcare has great potential for improving patient care and advancing medical therapies despite overcoming certain hurdles [11], [12].

This paper presents the Meta-Verse Assisted Healthcare Body Sensor Network Architecture, which offers real-time healthcare data monitoring based on edge cloud networks. The objective is to collect data from different sensors and train it on virtual metaverse edge nodes for prediction and classification. The paper has the following contributions.

- We present the meta-verse-assisted healthcare body sensor network architecture, which offers real-time healthcare data monitoring. The architecture comprised metaverse healthcare and fog nodes for data generation and processing.

- We present the offloading scheme to transform the workloads from local devices to fog nodes.
- We devise the scheduling to allocate the workloads to the resources without any violation.

The paper is organized as follows: Section II is about the proposed architecture, Section III is about the proposed methodology, and Section IV is about performance evaluation. Section V is about the conclusion and future work.

II. Proposed Architecture

As shown in Figure **??**, the proposed architecture consisted of different tasks-related sensors. All the sensors, such as non-invasive heart-rate pulse, smartwatches, and other sensors, are connected to the human body. These healthcare sensors are connected to mobile devices. The application is installed on mobile devices and consists of different tasks. For instance, heart-rate monitoring, blood pressure, body temperature, oxygen level, and bio-data.

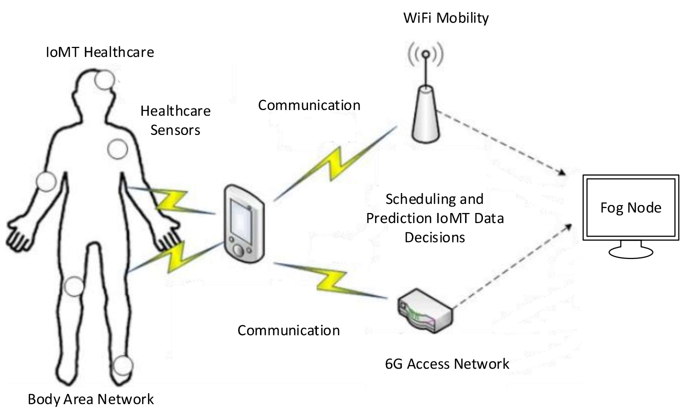

Fig. 1: Proposed Metaverse Healthcare Body Area Network Architecture .

We show the body area network healthcare application by notation A that consisted of different tasks, e.g., T. Each task has original data, e.g., D. Therefore, we formulated in the following way, e.g., $A, T, D\{t, d = 1, \ldots, T, D\}$. We show the local mobile devices as follows. e.g., $M\{m = 1, \ldots, M\}$. The mobile devices have the following computing capabilities: resources represented by ϵ_m and speed ζ_m. We show the healthcare fog nodes as follows. e.g., $K\{k = 1, \ldots, K\}$. The fog nodes have the following computing capabilities: resources represented by ϵ_k and speed ζ_k.

The local processing time of healthcare sensors is determined in the following way.

$$Local = \sum_{t=1}^{T \in A} \sum_{m=1}^{M} \sum_{d=1}^{D} \frac{t, d}{\zeta_m}, \forall t = 1, \ldots, T. \quad (1)$$

Equation (1) determines the local processing time of sensor data and tasks on mobile devices. All the data was offloaded to the fog nodes, and the communication time was as follows:

$$C = \sum_{t=1}^{T \in A} \sum_{d=1}^{D} \frac{t, d}{up_{bw}}, \forall t = 1, \ldots, T. \quad (2)$$

Equation (2) determines the communication between local mobile devices and fog nodes. All the tasks are scheduled on fog nodes, and the time is determined in the following way.

$$Local = \sum_{t=1}^{T \in A} \sum_{k=1}^{K} \sum_{d=1}^{D} \frac{t, d}{\zeta_k}, \forall t = 1, \ldots, T. \quad (3)$$

Equation (3) determines the fog processing time of sensor data and tasks on fog nodes.

We determine the total time of all tasks in the following way.

$$Score = \sum_{t=1}^{T \in A} Local + Com + fog, \forall t = 1, \ldots, T. \quad (4)$$

Equation (4) determines the total makespan processing time in terms of the score of sensor data and tasks on mobile devices and fog nodes. It increases the score when all tasks are executed with minimum end-to-end time.

III. Proposed Meta-CNN Enabled Offloading and Scheduling

This paper presents the meta verse body area network offloading scheduling (MBANOS) based on a convolutional neural network (CNN) for all healthcare sensor data and their tasks. We present the MBANOS algorithm framework that consists of different schemes, such as local processing, offloading, and CNN-enabled scheduling, along with metaverse fog nodes.

Algorithm 1: MBANOS

```
Input  : {D, A, T, M, K, C
Output: min Total;
begin
    Initialize healthcare application A;
    for (t = 1 to T) do
        for (d = 1 to D) do
            Start Process Locally on Mobile Devices
              based on equation (1);
            Initialized tasks:t, d, m;
            if (t, d, m==1) then
                Offload workload to fog nodes K based
                  on equation (2);
            Search optimal meta fog nodes for
              scheduling;
            Extract the features of data based on given
              data D;
            apply CNN.A, T, D, K based on equation
              (3);
        End scheduling;
    End Application;
End main;
```

Whereas Algorithm 1 starts with an application that consists of different tasks. However, these tasks are related to healthcare tasks with original data collected from different sensors. Algorithm 1 has the following steps to complete the execution from mobile devices to fog nodes.

- Algorithm 1 takes the different parameters as an input: D, A, T, M, K, C.
- All the data collected from different sensors D. The application consisted of different tasks, such as T. Therefore, on the local devices, it schedules the application tasks locally based on available resources as determined in steps 1 to 4.
- All the data is offloaded to the metaverse fog nodes for processing.
- All the body area networks trained their data based on convolutional neural networks as defined 6 to 12.
- The mobile and fog are metaverse computing nodes that provide the virtual environment for the execution of all tasks of the application as determined in steps 1 to 12.
- Algorithm 1 terminates until tasks are executed based on given data in the architecture.

Algorithm 1 is adaptive offloading and scheduling schemes and runs all virtual data of healthcare sensors in the clinical healthcare fog nodes for executions.

IV. Performance Evaluation

In the performance evaluation, we present the simulation environment and configuration related to mobile devices, metaverse fog nodes, and datasets related to body area networks. Table I shows the different features such as different subjects'

TABLE I: IoT Body Area Network Sensors Data Parameters

T	Heart (BPM)	BP (mmHg)	Oxygen (%)	Temp. (°C)
1	72	120/80	98	36.6
2	75	122/82	97	36.7
3	80	125/85	99	36.5
4	78	118/78	96	36.8
5	70	119/79	97	36.6
6	74	121/81	98	36.7
7	77	124/83	96	36.5
8	82	123/82	99	36.8
9	79	117/77	97	36.6
10	76	120/80	98	36.7
11	73	122/82	97	36.5
12	81	125/85	99	36.8
13	78	118/78	96	36.6
14	75	119/79	97	36.7
15	72	121/81	98	36.5
16	80	124/83	96	36.8
17	77	123/82	99	36.6
18	74	117/77	97	36.7
19	79	120/80	98	36.5
20	76	122/82	97	36.8

heart rate, blood pressure, temperature, and oxygen level saturation. These sensors are connected to the human body, where the body area network connects these sensors as shown in Table I. Table II shows the mobile configuration in terms of mobile central processing unit, storage, and speed regarding

TABLE II: Mobile Devices Configurations

Device ID	RAM (GB)	ROM (GB)	CPU (GHz)	Speed (Mbps)
1	4	64	2.0	150
2	6	128	2.2	200
3	3	32	1.8	100
4	8	256	2.8	300
5	4	64	2.1	150
6	6	128	2.5	250
7	8	256	3.0	400
8	3	32	1.6	100
9	4	64	2.0	150
10	6	128	2.4	200
11	8	256	2.8	300
12	4	64	2.1	150
13	6	128	2.3	200
14	3	32	1.7	100
15	8	256	2.9	300
16	4	64	2.2	150
17	6	128	2.6	250
18	8	256	3.1	400
19	3	32	1.8	100
20	4	64	2.0	150

random access memory (RAM). These mobile devices collect data from healthcare network sensors in the body area.

TABLE III: Fog Servers Configurations

Server ID	RAM (GB)	ROM (TB)	CPU (GHz)	Speed (Gbps)
1	64	4	2.6	10
2	128	8	3.2	20
3	32	2	2.4	5
4	256	16	3.5	40

Table III consisted of different meta-verse fog nodes with different ROM, RAM, speed, and storage configurations. The meta-verse virtual environment is implemented as fog nodes. Figure 2 shows the performances of body area network applications with different methods. We considered the different methods as baseline approaches, such as body area network (BAN), meta-verse body area network (MBAN), and meta-verse body area network scheduling (MBANS). We compared the performance of these methods with the proposed scheme in

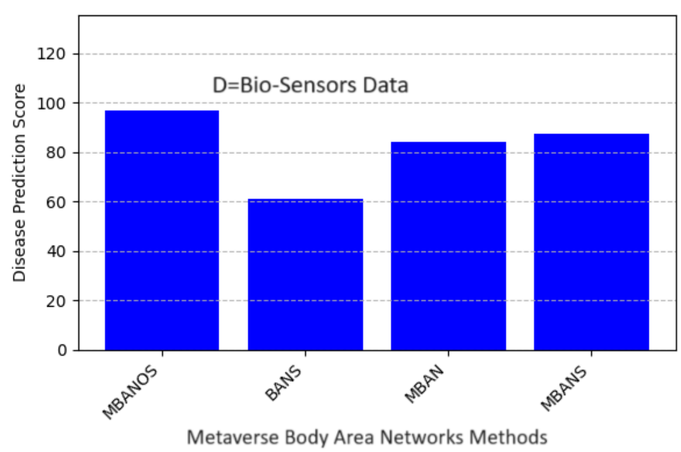

Fig. 2: Score Prediction of Metaverse Healthcare.

the suggested architecture. Figure 2 shows that MBANOS has a higher score, which is equal to 80 for all tasks as compared to existing methods. Figure 3 illustrates the performance of body

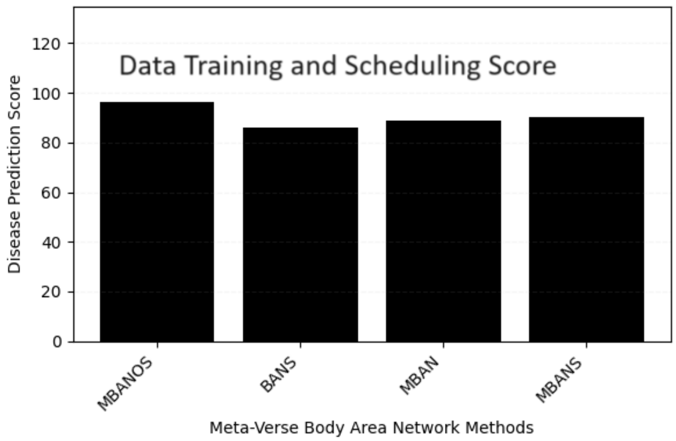

Fig. 3: Score Prediction of Metaverse Healthcare.

area network applications using various approaches. We evaluated different methods, including body area network (BAN), meta-verse body area network (MBAN), and metaverse body area network scheduling (MBANS), as baseline approaches. The performance of these methods was compared with the proposed scheme in the suggested architecture. As depicted in Figure 3, MBANOS achieves a higher score of 80 for all tasks than the existing methods.

V. Conclusion and Future Work

The utilization of body area network-enabled healthcare services has been rapidly increasing in practical applications. The primary goal is to enable real-time healthcare monitoring from various remote services. However, the current body area network architectures for healthcare services are neither sufficient nor optimal.

In this paper, we introduced the Meta-Verse Assisted Healthcare Body Sensor Network Architecture to provide seamless healthcare services to different subjects. This architecture integrates metaverse technology, healthcare sensors, and fog nodes to deliver uninterrupted services. We considered heterogeneous devices, such as medical sensors (e.g., heart rate, oxygen, blood pressure, and temperature), which are connected to mobile devices and metaverse fog nodes to process the healthcare application tasks of subjects.

We proposed the Metaverse Body Area Network Offloading Scheduling (MBANOS) system, based on a convolutional neural network (CNN), to handle all healthcare sensor data and tasks. Simulation results demonstrate that MBANOS outperformed existing methods, achieving the highest score in data processing across different nodes, thereby effectively maintaining subjects' healthcare in practice.

Future work will focus on further optimizing the Meta-Verse Assisted Healthcare Body Sensor Network Architecture. This includes improving MBANOS's efficiency and robustness, integrating advanced machine learning algorithms, and expanding the system to accommodate a broader range of medical sensors and devices. Additionally, real-world deployment and testing in diverse healthcare environments will be essential to validate the system's performance and scalability. Enhancements in security and privacy measures will also be a priority to protect sensitive healthcare data.

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