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Real Time Health Monitoring For Palliative Patients through MSE-WBAN Architecture

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Abstract

The mobile-Health (mHEALTH) is the application of digital technology in health care services to bring the health care services into a digital format and to introduce the culture of digitalization in health-related matters. There are many varieties of health apps available to purchase from apps stores which are really helpful for patients. Around 325,000 mHEALTH applications are available now. Development of tiny sensor networks that can be implanted inside or out- side the human body gave a novel development in the field of mHEALTH. The sensor devices can access the vital parameters from the human body and can be sent to any near-by personal devices through any of the network protocols like Bluetooth, Zigbee etc. The sensor devices change the mHEALTH application more dynamic and ensure the consistency of data by the real time monitoring. The paper proposed a new architecture for mHEALTH with multiple sensors to monitor the vital signals of patients in a palliative clinic and proved that the architecture is more efficient and consistent than existing mobile health applications.

Keywords

mHEALTH; Wireless Sensors; WBAN; WSN; Sensor Nodes

Introduction

The mHEALTH works on 4 A's i.e. "Anytime, Anywhere Access with Always best-connected features" which gave birth to the realization of emerging wireless communication and network technologies, that support health care over the assorted infrastructure. This is a prevailing means to improve the quality of health monitoring and provided an alternative to current methods of health care conveyance which have accepted in some countries. So, the existence of mHEALTH and e-Health is supporting the people of different category as well as the health care system with a versatile dimension.

This paper presents the role of WBAN to widen the application of mHEALTH in the health care service. Initially the mHEALTH is just the application of mobile phones, but the connection of WBAN with this make the application in to a new face and as a part of health science and bioscience. mHEALTH is the new offspring's of the information technology, which is supported by the smart phones and changed as the part of IoT.

Now it is mostly used in developed countries health monitoring system. It also has some technical, social, economic and professional confusions and consequences. The Body Area Network is a novel area that can be incorporated with the mHEALTH to perform diagnosis more clear and relevant by collecting the vital signals from the patient's body, rather than the oral communication through the mobile devices. So, the use of WBAN gives the mHEALTH a new face and acceptance. The usage of WSN to implement real time health monitoring by implementing them inside or outside the body constitute the WBAN. They monitor the bio parameters such as blood oxygen saturation, blood pressure and heart beat rate.

The radio frequency based wireless networking technology is used in this. The facility provides real time feedback to the user and medical person. In WBAN each medical sensor monitors different vital signals and the system consist multiple sensor nodes that monitor body motion and heart activity. The WBAN is a communication network between humans and computers through wearable devices. It uses techniques from wireless sensor network and adhoc networks.

The WBAN and WSN differ in their deployment, mobility and data rate. In the case of WBAN the number of sensor nodes deployed are equally important and only added when they needed for application. In WSN it is often deployed in places that may not easily accessible by operators and it requires more nodes to compensate for node failure. In the case of mobility WBAN nodes share the same mobility pattern whereas WSN are usually stationary.

Basic Structure of Sensor Nodes

A wireless sensor node contains number of sensor nodes connected wirelessly each other. Individual nodes contain a process unit, memory unit, power supply, radio frequency transceivers and sensor board. The applications of sensor nodes are multidimensional. The activity may include event detection, location sensing etc. Individual nodes are self-regulated.

The sensors communicate each other according to routing protocols. They communicate with adjacent nodes to share collected data. The data will be sent to the receiving node and the receiving node is called sink node. It is a mediator between WSNs and internet/intranet.

The sink has continuous power supply and so it can join and support all kinds of network structure and architecture. The sensor nodes are having long life time it is mainly because they use their energy only for transmitting and receiving data. They are very rarely utilising their energy for computation and processing [1,2].

The restricted hardware source and power limitations keep away sensors from working with transmission of data with large size like video, pictures and stream data. The WSN uses the Complementary Metal Oxide Semiconductor camera for capturing images. They are low quality images. The multimedia wireless sensors are completely differing from normal WSN. They differ in network design, routing protocol, encoding, decoding etc. The QoS parameters are also different from that of conventional WSNs [3,4].

The hardware structure of multimedia WSNs included, sensor nodes embedded with low-cost video camera or sound recorders and sensor boards. During the sensing duty of a sensor like intruder detection or other environmental phenomenon, the video camera or sound recorder are activated. The network topology of the WSNs will change depending on the application as well as the network architecture. The processors of WSNs are in-built. They are also up-to-dated. The microprocessors are designed for embedded applications. The processor inside a sensor node is a small computer inside a single chip that contains a processor core, memory and I/O peripherals. The basic architecture of a sensor node is given in Fig. 1. The architecture contains a sensing board, transceiver and the processing unit. The processing unit contain processor, memory and physical layer [5-7].

Figure 1: Hardware architecture of sensor node.

Mobile Health through Mobile Devices

The existing architecture consists of a smart phone that controls and co-ordinates the various request from the patients and reply or solutions from the clinic or physicians. The embedding of sensor devices in patient's body or surroundings can transfer the vital signals in real time. The mHEALTH services can provide diagnosing and continuous monitoring of the patients with the use of WBAN architecture.

The Fig. 2 shows the existing state of mHEALTH. The mHEALTH application through mobile devices has another phase such a built-in mobile apps for various health care services like pulse rate calculation, accelerometer to record the movement of patient, monitoring blood pressure etc. The applications developed in mobile phones are mostly in android software. Accuracy and consistency of the application is not reliable.

Figure 2: Structure of mHEALTH application through smart phones.

Literature Review

The World population is changing at 1.13% each year. The world sees a population boom at the rate of population increases, the health care facilities do not increase. To enhance the health care facilities variety of tools is given to the health care providers. New developments and research in this field are going on. The growth of technology and its applications in medical research and development have given easy and attractive facilities and tools to the medical practitioners and in healthcare field.

As a result, the wireless monitoring health schemes termed as WBAN will turn out to be a part of portable healthcare with concurrent management. In future wireless monitoring medical

systems will be in vogue. Numerous devices that are wearable or embedded in body or clothes are in use. These small devices that form a network in/on the body are termed as WSN. Such sensors accumulate various health statistics like blood pressure, heart beats rate, arrhythmic rate, brain liquid pressure, etc. Medical dreams of medical men of last centuries are a reality today [8,9].

A WBAN is kind of WSN Lai, et al. The sensors are of different types based on their operation [5]. It uses some communication standards for their operation Johny and Anpalagan, Seyedi et al. [10]. The applications of sensors are in variety of fields such as medical, consumer electronics or personal entertainment and other Karulf. The sensors are the devices that can be either inserted inside the human body or put on as a vest. The sensors are capable to appraise and calculate various natal practices of the human body as long as timed statistic. The IEEE802.15.6 and IEEE 802.15.4j standards are particularly structured for clinical WBAN's [11-14].

The topic of concurrent mobile healthcare scheme for managing the aged patients from inside or outside places is scrutinized Bourouis et al. [1]. The major components of the mobile health monitoring system are bio-signal sensors and a smart phone. The sensors catch the vital readings from the body and transmit the readings to an intelligent server through GPRS/UMTS network. The sensor system is capable to monitor the flexibility, position, and interpretations of vital signs of the aged patient from far distant. In Lee and Chung, the study is on the designing of sensor connected smart shirt. The shirts evaluate real time readings of bio-parameters such as Electrocardiogram (ECG) and acceleration signals from the patient and make the patient under a medical surveillance. The conductive fibbers in the shirt help to collect the readings. It uses the IEEE 802.15 network to transmit the measured body signals to the server. The sensors are small in size and consume less power. In this study the authors proposed an adaptive filtering method to reduce the noise associated with the ECG signals.

A windows Mobile based system for watching vital parameters has been described in Pereira et al. [9]. The system describes on a body sensor network that record readings and collect bodily statistics. The system uses Bluetooth to conduct details from the sensor network to a mobile device. The dependability and stoutness of the suggested scheme has been corroborated by the authors. The experimental results proved the efficiency of the system in monitoring the biological statistics of diseased person under agility condition. A comprehensive WBAN system has been designed in Yuce [14]. The recommended system uses medical bands to collect biological data from sensor nodes. The medical bands decrease the interfering between the sensor device and other existing network devices.

A multi-hopping technique has adopted in the study to increase the operating range using a medical gateway wireless board. The gateway connects the sensor nodes to a local area network or the Internet. With the use of internet, the healthcare experts can access patients' bodily data

from anywhere at any time. The unauthorised mobile health apps and sensor enabled health monitoring systems may generate false alerts. Hence, the reliability and security is a major problem in these applications. To ensure the security some machine learning methodologies have been suggested in Clifton et al. [3]. In the study data spawned by the sensors are joined with clinical interpretations and offer timely cautioning of severe biological variations in the patients. The study results are tested at Oxford university hospital, and it proved the efficiency that the data collected by the wearable sensors can be combined by the proposed system effectively. So the clinical staffs make important decisions about the patients based on this data.

A cloud supported health monitoring has been introduced in Parane et al. [8]. The authors have projected a Cloud based Intellectual Healthcare Controlling System (CIHCS) for providing medical response to a patient through cloud. By using cloud computing devices the system collects patient's data and supply the data to a distant location. The mobile devices are considered as a promising tool to observe and manage patients' own health status. Still these devices have some innate precincts in computation or data intensive tasks. A novel hybrid mobile cloud computational clarification has been recommended in Wang, et al., to overcome these limitations [13]. The study introduced a mobile cloud-based electrocardiograph monitoring system. The experimental results show that the proposed system can pointedly enhance the probable mobile based medical monitoring system in terms of diagnostic accuracy, implementation adeptness, and energy proficiency.

To monitor the physical status of a pregnant woman with preeclampsia a novel health management scheme that has been discussed in Dunsmuir et al. It is related with the community based health care system. In the study the authors explained that the clinical person collects symptoms and perform clinical measurements at the patient's home. It could be used to predict the risk level of a patient. Based on the predicted risk level the system provides approvals for treatment, referral, and reassessment. A tele-healthcare system for managing electrocardiographic and temperature readings has been described in Tello, et al. [11].

In Koch, et al. the study explained the direct involvement of patients and relatives into the system development process, challenges in organization of the health care system [4]. The study explored a new patient role as an active participant and supervisor in health care process. The study developed an inter-disciplinary working group results in a better mutual understanding of different work environments. It also helped to exchange knowledge and experiences between different user groups and user as a developer.

The study in Bhuyan, et al., described on the use of mobile health application on smartphones. it is mainly focused in US adults [2]. The study explored the statistics of medical applications available in mobile phones. The patients or caretakers used the application for various medical related communications. The study lo analysed the potential of mHealth applications I primary health care, reducing cost and improve the quality of health care.

The study in Lattie et al., explored how mobile health apps can help to improve mental health of patients. The mental health app is popularly used by physicians with great interest [6]. The study rates various mental health supporting apps to manage and support mental health. In Bourouis, et al., the study proposed a safe data communication design in WBAN for data integrity [1]. It was a user oriented design that shares data through all the sensors with the usage of a secret key. The architecture reduced the processing requirements and extra memory requirements. The study proved that the system structure reduced the waiting time of real time traffic in BAN [6].

Methodology

The MSE-WBAN Architecture

The study proposes the Multi Sensor Enabled Wireless Body Area Network (MSE-WBAN) architecture, in which the patient's body forms a body area network with the inter connection of Wireless Sensor Network. The architecture can ensure continuous monitoring of the patients through the signals sent by the sensor devices implanted inside the body or in its peripherals. The signal can be stored in a server and the doctors or the nurses can read it as needed. The detailed architecture has shown in Fig. 3. The major aims achieved in this architecture are:

1. Ensure centralized control over health data
2. Ensure security of health signals
3. Continuous monitoring of the vital signals

The hemolysis curve for sickle cells show a similar “S-shaped” pattern as normal red cells on exposure to decreasing solution osmolality. Surprisingly, we found that sickle erythrocytes showed more resilient to changes in osmolality. The hemolysis threshold for sickle red blood cells of was 170-mOsM, more resistant (less fragile) compared to the 190-mOsM for normal red cell.

The previously established osmolality for normal erythrocyte hemolysis is 190-mOsM and some of the factors that influences red cells hemolysis in a hypotonic solution such as variation in cell size, age of the red cells and hemoglobinopathies were discussed [7]. In this study, the threshold for sickle red cells hemolysis is 170-OsM, indicative of more resistance to changes in osmolality than normal cells. Although the osmolality dependent exposure curve for normal and sickle cell erythrocytes show a similar “S-shaped hemolysis pattern” (Fig. 2), a left shift and decreased Hb content is exhibited in the sickle erythrocytes curve. This is true for the same osmolality up to 150-mOsM, more resilient of sickle cells compared to normal red cells. This agrees with previous report that red cells with normal Hemoglobin (HbAA) were more susceptible than sickle cell Hemoglobin (HbSS) to saline hypotonicity [11,12]. Disorder in beta

hemoglobin and perhaps other hemoglobinopathies lead to highly resistant red cells on exposure to varying degrees of hypotonic solutions.

The difference in osmolality threshold for hemolysis between normal and sickle cell blood can be explained by the variability in cell sizes and the number or proportion of sickle-shaped (sickling) red cells in the blood. Erythrocytes have an average diameter of 7-8 μ m, but sickle red cells show remarkable heterogeneity in density, morphology, and rigidity making the affected cells more rigid and “sticky” compared to normal RBCs [13]. A steeper curve reflects the more uniformity in the sizes of the cells, which allow the cells to reach their osmolality threshold for hemolysis at approximately the same time. The proportion and variants of hemoglobin in sickle cell disease may explain the difference in osmolality threshold for hemolysis between the normal and sickle cell blood. Evidence suggests that sickling in sickle cells blood constitute about 5-50% of the total number of red cells in the peripheral smear [14]. The higher the proportion of sickle and fetal hemoglobin compared to the major Hemoglobin (HbAA), which generally constitutes approximately 97% of the total hemoglobin in normal red cells, the more prominent the right shift or differences between the two specimens [13]. Previous study demonstrated that the severity of sickle cell disease increases with age and the proportion of sickle shaped cells [14]. The sickle-shaped cells are more likely to take a longer time to rehydrate, swell and lyse in a hypotonic environment compared to normal cells. When osmolality decreases to 150-mOsM, both normal and sickle red cells lysed releasing approximately about the same Hb content in solution after 30 minutes of incubation (Fig. 2). For the same hematocrit, sickle cell patients have increased fetal hemoglobin but reduced total hemoglobin compared to normal cells [12-14]. It was however, surprising that we measured approximately the same hemoglobin content in the supernatant at much lower osmolality in both normal and sickle red blood cells. While the total hemoglobin content is low in sickle cell disease, it is likely that the membrane bound fraction decreased, thus favouring an increased proportion of the cytosolic to membrane bound fractions of hemoglobin in the supernatant following hemolysis. Hemoglobin exist as cytosolic and membrane bound fractions [13].

In Fig. 3, the proportion of retained Hb/GPD decreases with decreasing solution osmolality. This decreased is even more significant in sickle red cells compared to normal cells at 65-mOsM solution. We attribute this to, perhaps the compromised structure of the sickled beta subunit of hemoglobin impacted the cytoplasmic to membrane bound ratio. Because hemoglobin subunits exist in both cytoplasmic and membrane fractions, the retained hemoglobin at much lower osmolality are most likely membrane bound fractions. The washed off fractions following complete hemolysis are cytoplasmic, and perhaps constituted mostly the compromised beta-subunit.

The severity of sickle cell disease correlates with the proportion of sickle-shaped cells in the peripheral blood smear. Severe hemolysis and vaso-occlusive crisis are more likely and frequent when the fraction of sickle-shaped cells are high. Perhaps, exploring the osmolality

threshold for sickle cell blood as a function of the proportion of sickle-shaped cells is worthwhile. Hydration status during the fluid management/treatment is critical to alleviating the acute pain that sickle cell patients endure during vaso-occlusive episodes [12-14].

Figure 3: The MSE-WBAN architecture.

Figure 4: The layers in MSE-WBAN architecture.

The architecture shown in Fig. 3 and 4 consists of user layer, device layer, protocol layer, remote monitoring layer and the data storage layer. The user layer deals with the different users who wear the sensor devices. The second layer is the device layer which deals with the set of devices constitute the architecture. It includes sensor nodes which collect vital signals from the body and they send the signals to the mobile devices wirelessly.

There should be gateway that gathers the signals collected by different signals from the body and inform the users. These are the outside personal devices including smart phones and are called Body Control Unit. The third set of devices in the device layer is the monitoring device;

it stores the database for data storage. This storage server has to maintain the security of data as well as the authenticity. The third layer represents the various protocols that control the flow of signals to the mHEALTH centre through various intermediate wireless devices. Varieties of protocols were designed by different studies to make the data transfer efficiently.

The protocols are designed for the MAC layer they must be low power consuming accurate and with less latency. The protocol should efficient enough to give good performance on varying traffic load. Some popular protocols are TMAC, Zigbee MAC, SMAC and Baseline MAC. The protocols are designed using wireless LAN technology and cellular technology.

TMAC: In this protocol the node is awoken for particular period that is called active time. It is a duty cycling protocol and the duty cycle changes according to the traffic load of the network. It is directly proportional to the traffic load. The protocol is able to handle varying load with low power consumption.

SMAC: It is similar to TMAC but having fixed duty cycle. The protocol is not suitable for handling continuously varying data rate in WBAN.

Zigbee MAC: The protocol can use two schemes-CSMA/CA or TDMA. While using CSMA/CA mechanism this protocol gives average performance but using TDMA it reduces the power consumption up to a great extent.

Baseline MAC: This protocol uses CSMA/CA scheme. In terms of throughput the performance of the protocol is average but in the case of energy consumption it is above average. In cellular technology the architecture uses GPRS, 3G, 4G etc. are used. The remote monitoring layer consist the clinical persons who are continuously monitoring the signals. The centralized control of the data can be ensuring by this layer. The layer functionality includes SMS services for medication, information about the level of emergency, video conferencing facility as needed etc. The lowest layer is the storage layer which can be assembled wit remote monitoring layer. Here the entire signal data is stored in digital format including the details of user. It could be provided to the doctor as needed with security conditions. The flow diagram of the architecture is given in the Fig. 5.

Figure 5: Flow diagram of MSE-WBAN architecture.

The study conducted a pilot work based on this architecture by connecting two sensors in body and the signal collection is done through the smart phone, it is sent to a physician's remote system. Through the remote monitoring service from the doctor the patient is continuously

under the surveillance of the clinic. The data can be stored in the storage device of clinic. The doctor instructs medicine and other direction to the patient through the SMS service. The nearby palliative clinic implemented the architecture and through the video conferencing the nurses give advices and provide a friendly chat with the patient. For less number of patients, the architecture gives successful result.

In the existing application the people who were known about the mobile app for health care after analysing the result they contact the doctor and discuss on the result obtained. It is only a single person-oriented activity. So, there is no continuous evaluation of the health-related problems and it is just the usage of mobile applications. With the implantation of sensors in human body the continuous monitoring and give new phase to mHEALTH. This study proposes the MES-WBAN architecture for the continuous monitoring of the patients and for establishing an authorized mHEALTH clinic. By designing the architecture, the metrics considered are throughput, packet receiving ratio and accuracy of data collected.

The data are collected from health app through mobile phones as well as from sensors connected with body. The mobile apps like Herat Watch, Cardiograph classic, Quardio. The digital readings are recorded. The blood pressure checking apps used are Blood pressure DB, Blood pressure Diary. Some sensor devices like EIProcon and 8511A high pressure sensor. The heart rate monitoring sensor SEN-11574 and HRM watches. The readings are recorded separately in different intervals of time. After analysis it is proved that the metrics packet receiving rate and throughput are high in sensor devices than mobile applications.

Data Analysis and Implementation

The metrics evaluated through this architecture are throughput and packet receiving ratio. To calculate the parameters arranged a test bed with sensors connected in body, and a smart phone with health care application. Monitor the data from sensors and from mobile app. We noticed that sensor devices continuously sending data to the mobile in which it is connected, or we can read the readings from the device itself. In mobile app the specific application sent data as required by the person. It does not give continuous readings. We have used two sensors for taking readings of heart rate and the other for blood pressure. The mobile app chosen is also with the same usage. The analysis of readings from different persons are tabulated in the following Table 1 and 2.

Day	Total	Server 1		Server 2	
		Arrival/minute	Service/minute	Arrival/minute	Service/minute
Monday	Total arrival/service	36	30	51	54
	Average arrival/service	12	10	17	18
Tuesday	Total arrival/service	75	47	52	45
	Average arrival/service	25	15.6	17.333	15
Wednesday	Total arrival/service	31	26	50	46
	Average arrival/service	10.3	8.66	16.66	15.3
Thursday	Total arrival/service	42	28	35	24
	Average arrival/service	14	9.3	11.6	8
Total for the week	Total arrival/service	184	131	188	169
	Average arrival/service	61.3	43.62	62.59	56.3

Table 1: Throughput analysis from sensors.

Day	Total	Server	
		Arrival/minute	Service/minute
Monday	Total arrival/service	40	24
	Average arrival/service	10	6
Tuesday	Total arrival/service	29	26
	Average arrival/service	7.25	6.5
Wednesday	Total arrival/service	46	29
	Average arrival/service	11.5	7.25
Thursday	Total arrival/service	28	15
	Average arrival/service	7	3.75
Total /week	Total arrival/service	143	94
	Average arrival/service	35.75	23.5

Table 2: Throughput analysis from mobile app.

The data recorded in different intervals of different days are tabulated and calculated throughput and packet receiving ratio of both mobile app and sensor enabled application. It is noted that the sensor enabled application give continuous readings while the mobile app could not take readings in a continuous manner. Waiting time and queue length for diagnosing through mobile app as well as the newly proposed architecture are calculated. So, the proposed architecture can reduce the delay in diagnosing more when compared to the existing mobile applications of mHealth.

During data collection the sensor devices gives readings regularly whereas the mobile app readings are made forcefully in order to record the readings. With this data we fix the parameters like throughput and packet delivery ratio in both cases. While calculating the throughput we could not get as much data as in the case of sensor devices.

Result and Discussion

The architecture is tested with the patient's in a palliative clinic. Around 35 patients are registered in the clinic. Earlier the health visitors and nurses visit the patient's home and take the readings. There are chronic patients of cancer, asthma, paralyzed and other diseases of old age. Among these for taking data we have connected the sensor devices for 5 people, the readings are recorded and send through the mobile devices of their bystander.

The collected data are recorded and analysed from the near-by clinic with two doctors, which is represented as server1 and server2 in the tables. It has proved that the existing mobile application for health care is not consistent and accurate. The sensor enabled architecture can improve the efficiency of services by increasing throughput, packet receiving ratio, and accuracy of data. The metrics are evaluated and explained through figures. So, the multi sensor enabled architecture can improve the mHEALTH service to a great extent.

The results are plotted in Fig. 6-8. From Fig. 6 it is recorded the throughput for sensor enabled architecture is 68% and for mobile app it is 32%. It is because the sensors are capable of monitoring the implanted or inserted environment continuously. Fig.7 explains the packet receiving ratio during the observation. The sensors can produce continuous data and so the number of packets per minutes is very high when compared to the mobile app. The concept of continuous monitoring during mobility of patient is quite difficult in the case of health applications through mobile devices.

Fig. 8 shows the readings recorded though mobile app for heart rate monitoring and the same through specific sensors for sensing heart beat rate. It is very obvious that the readings from sensors are almost near to the correct value of heart beat rate. The mobile app readings are not

consistent and not accurate. The values of parameters considered from both mobile app and sensor devices are tabulated in Table 3.

Parameters	Mob App	MSE-WBAN Architecture
Throughput in Minutes	23.5	49.96
Packet Delivery Rate in Minutes	35.75	61.3

Table 3: Parameters evaluated.

Figure 6: Comparison of throughput.

Figure 7: Packet receiving ratio in mobile applications and sensors.

Figure 8: Heart rate recorded from different mobile apps and sensor devices.

Conclusion

The study proposes a stable architecture for the mHealth. The study compares the current mHealth application through mobile apps with the MSE-BAN architecture. The health care applications through mobile applications do not have any structured format. Based on the companies of mobile manufacturing or according to the supporting operating system in the phone the availability of application may change. Except the continuous monitoring of the vital parameters the applications can communicate with medical professionals to discuss on their health related matters.

The continuous monitoring of the patient is possible through the proposed model. So, the emergency services for bedridden patient can be given through the proposed method. For the evaluation of parameters, the readings of body signals are recorded for different days in varying time intervals. It has proved that the number of incoming signals is high in the proposed model than the existing mobile health application. The parameters throughput and packet receiving ratio in both cases are evaluated in the study and proved the efficiency of the model.

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