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Decision Making Patient Assistive Strategies in Wireless Body Area Networks for Remote Healthcare System

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Abstract*: Wireless Body Area Networks (WBAN) helps in pervasive health monitoring of a patient, thus assists doctors in diagnostics. WBAN nodes on the patient communicates with the doctor at any remote place and informs the patients' condition. In this paper, the mathematical modelling techniques, which assist in decision-making, namely TOPSIS, Integer Linear Programming and Fuzzy Logic are analyzed effectively.So decision making can easily help for analyzing and finding a suitable decision. WBAN diagnoses' in real-time. The proposed methodologies using different types of decision making systems will definitely help the patient in terms of real-time monitoring of his data through IoT. Electronic Medical Records are updated within certain time periodically via standard mobile devices such as smart-phones and Personal Digital Assistants. The results give a better understanding of healthcare analytics for WBAN for assisting patients with WBAN sensors. The simulation results and analysis of different decision making methods are discussed . There is an expert repository of multiple doctors at a remote place. The patient's details are stored in the hospital server which can be used by remote doctors for any analysis. The patient is monitored continuously by a doctor and data is remotely acquired. In case of any emergency, the doctor advises an e-prescription to the nurse, so she takes an immediate required action. All these proposed schemes are fast and reliable decision methods for WBAN. These methods has a significant impact on WBAN. In future, this technology will be tried with different patients and analysis will be done in terms of network longevity and six V's.

***Index Terms*: multi-criteria decision making, integer linear programming, sensor network, fuzzy logic design.**

I. INTRODUCTION

The environment's activity patterns and behavior are captured by sensors as potential signs [1]. Early treatment is possible by in-home sensors. Identifying the problems early provides opportunity to focus on independent living atmosphere. To detect any health issue at a very early stage is very complex with the available sensors. New innovations must come for long use of sensors. The algorithms developed must answer the questions of the aged people and must detect before any disease occurs. Wireless Body Area Network (WBAN) with Internet of Things can definitely give a pervasive environment for remote health monitoring. Correspondence between gadgets is made simpler and the advances in sensor and connectivity innovation are enabling gadgets to gather, record and break down information that was not available some time recently. In human services, this implies having the capacity to gather quiet information after some time that can be utilized to enable empower preventive care, to permit incite conclusion of intense complications and advance comprehension of how a treatment (normally pharmacological) is enhancing a patient's parameters. The capacity of gadgets to assemble information all alone evacuates the restrictions of human-entered information—naturally getting the information specialist's need, at the time and in the way they require it. The computerization decreases the danger of blunder. Less mistakes can mean expanded productivity, bring down expenses and upgrades in quality in pretty much any industry. Be that as it may, it's specifically compelling/require in medicinal services, where human blunder can truly be the distinction amongst life and demise. WBAN specifically helps to keep in line with remote doctors by suitable decision making mechanisms.

WBAN is described broadly at the first section. Secondly, the proposed decision making mathematical models suitable for WBAN are discussed one by one. Finally, the comparison of mathematical models and their advantages, usefulness and the applications are discussed.

II. WIRELESS BODY AREA NETWORKS

An architecture for WBAN over cellular networks [2] introduces the concept of prompt smart sensing and anytime-connected WBAN. All the transmission of physiological signals are done over cellular networks. It gives cardiac related diagnosis using coordinator and sink station and sends through GSM. Limitations are network lifetime is not increased because of the longer time duration of sensor nodes (i.e. transmission distance). Wearable sensors have turned out to be extremely well known in numerous applications, for example, therapeutic, entertainment, security, and business fields. In the restorative field, it is conceivable to screen patients' body temperature, heart rate, cerebrum movement, muscle movement and other basic information.

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A low power high determination Thoracic Impedance Variance and ECG checking has been produced and consolidated in a minimal mortar sensor shape for wearable ease heart medicinal services.

To test the utilization of in-home sensor information for catching well-being decay, a mechanized well-being ready framework has been produced. M-Health approach using mobile computing, mobile sensor and communication technologies for healthcare was explained [2]. This is certainly an advancement of e-well being frameworks from conventional work area telemedicine stages to remote and versatile designs. It displays a depiction of late developments in these zones and addresses a portion of the difficulties and future usage issues from the m-Health viewpoint. M-Health frameworks are made as a cooperative energy of rising portable restorative registering, therapeutic sensor advances, and correspondence advances. The pattern inside patient checking has been to permit the patient greater portability [3]. Limitations are larger power consumption and there is no swift medical care in emergencies and management of medical data in natural disorders. The (Fig. 1) depicts the flow of communication between patient and doctor through cloud analytics.

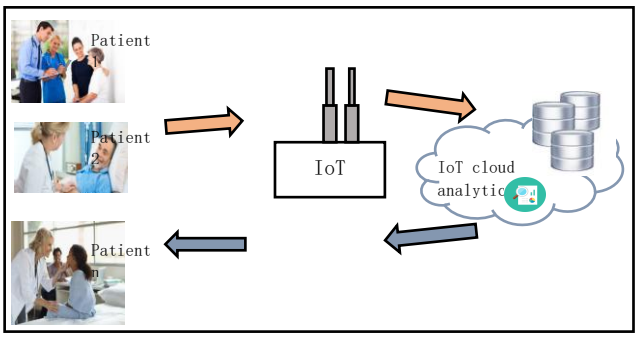

Fig. 1 Communication workflow through IoT

Following of exercises of numerous subjects, enabling pervasive and assistive healthcare for the elderly in their own homes [4] comes under healthcare. The mix of distributed computing and telemedicine guarantees to change human services conveyance [4] by advancing more moderate and higher quality social insurance. Cloud-based telemedicine additionally introduces various difficulties, for example, accomplishing high affirmation, interoperability, security and protection, and capacity flexibility. Albeit cell phones are clearly not intended for information or calculation serious assignments, outsourcing every crude datum to remote cloud servers isn't generally ideal. Some of the Limitations identified are Communication is expensive in terms of energy consumption, transmission delays, tradeoffs among bandwidth utility and battery life.

Wireless sensor network's communicate securely through fuzzy also [5]. A special wireless sensor network can be called as WBAN, where the sensors are arranged within specific distance enabling quality of service [6] for MAC parameters. Similarly for WLAN also parameters can be controlled and monitored [7]. IoT applications in wireless sensor networks are found largely nowadays [8].

Some of the issues in IoT based WBAN are described here:

(i) Network longevity is a must for sensor nodes. This depends upon the distance of separation of sensor nodes.

(ii) While taking IoT into account, security, interoperability, privacy and reliability must be addressed carefully.

(iii) The six V's are very important in case of Health. They are Value (Clinically relevant), Volume (Continuous monitoring of important signals), Velocity (High speed data processing for fast clinical support decision), Variety (Differences in data sources), Veracity (Data Quality) and Variability (Seasonal health effects).

(iv) Many IoT applications will be based on a deployed sensing, actuation, and communication platform (connecting a network of things).

IoT based WBAN should be of the form where the time critical issues must be solved and also the security of the data must be ensured. Hence control units are designed. Hospital with two control units is shown. If any disorder, the control units sends information through the medical server to the doctor. The doctor in turn sends the required steps to be taken by nurse. In case of any emergency, the doctor can alert the ambulance and take him to the nearby hospital and give him medication. Android was geared for smartphones and tablets.

The wearable body sensors extracts the information of patients' data and intelligently integrates the data into EMR via a base station using a power optimized operating and networking system. The collected data is transferred through IoT to doctor. The doctor monitoring the patient's details from a remote environment aware the nurse in case of an emergency situation through IoT to nurse's PDA. The nurse with the help of doctor's e-prescription gives the patient the needful.

III. MATHEMATICAL MODELS IN DECISION-MAKING

This section details the three decision making strategies of the proposed patient assistive scheme. Specific decision making strategies like TOPSIS, Integer Linear Programming and Fuzzy Logic are examined.

A. TOPSIS

TOPSIS is a Multi Criteria Decision Making (MCDM) [9], [10] system for selecting our desired optimal objective. The delay sensitive network selection problem in WBAN is chosen for analyzing the WBAN [11] parameters; end-to-end delay, network lifetime and throughput. It chooses the best and optimal solution for choosing an attribute. TOPSIS helps in comparing the different attributes of each alternative, normalize them and through the distance from each alternative, the ideal optimal solution can be found. It uses the step-by-step procedure for solving. At first, the original state is evaluated.

Then, the alternatives are designed [12], the criteria and the weights of the criteria are defined.

Pseudocode for MCDM
/ Selection of Multiple criteria (C1 C2 C3)
Throughput, Network lifetime, End-to-end delay
/ Selection of Multiple Alternatives (A1 A2 A3)
Network Models 1, 2, 3
/ Criteria must be maximized or minimized as specified accordingly

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The best optimal solution is found according to the shortest distance from its ideal solution. Hence this network with the help of mathematical formulation called TOPSIS [14] gives an ideal solution for the chosen WBAN parameters. The results are found using MATLAB and tabulated in an excel sheet. WBAN has sensors like ECG sensors, heartrate sensors, blood pressure sensors and temperature sensors for knowing whether the patient's health is in good condition o rnot. The health information must be passed through the gateway to reach the remote doctor.

Table 1. Alternatives and Criteria for assumed networks

Alternatives	A_1	A_2	A_3
Criteria			
C_1	0.2673	0.6852	0.3941
C_2	0.5345	0.5482	0.4729
C_3	0.8018	0.4796	0.7881

According to TOPSIS, any one network is chosen according to their rank and the cloud is updated with the health information.

Table. 2 Criteria with weights

S.No	Criteria	Weights
1	Delay	0.5
2	Network Lifetime	0.25
3	Throughput	0.25

The delay sensitive network is selected through the careful analysis of [15] – [19]. WBAN parameters i.e. end-to-end delay, network lifetime and throughput. Table 1 shows the decision matrix of the corresponding criteria and alternative. Here the end-to-end delay criteria must be minimized and network lifetime and throughput criteria must be maximized for saving the life of the patient. The Table. 2 above shows the criteria and their corresponding weights which is useful for determining the rank. Three network models are chosen with three WBAN parameters and are ranked according to TOPSIS topology in MATLAB as shown in Table. 3. The x-axis shows the weights and the y-axis shows the criteria which is to be minimized or maximized. TOPSIS results are available from [22].

Table 3. Network Models and WBAN parameters

S.No	Criteria	Network Model 1	Network Model 2	Network Model 3
1	Delay	0.2	0.4	0.6
2	Network Lifetime	10	8	7
3	Throughput	5	6	10

B. Fuzzy Logic

Fuzzy logic approach compares two or more input things and gives an output depending on those inputs. It has membership functions, rules and crisp values. The input membership functions, output membership functions and the rules are framed according to the output expected by the user. These deal uncertain situations with IF-THEN rules, AND logic, OR logic [12], [13]. The decision making unit decides the output with membership functions of both input & output and the rules. This helps in finding the approximate solutions of many complex problems giving outputs logically and mathematically.

Table 4. Constraints and decision variables - patient &doctor

	Patient			Objective Value	98000	
Doctor	P1	P2	P3			Limit of doctor's time available for each patient
D1	0	0	100	100	=	100
D2	100	0	0	100	=	100
D3	0	100	0	100	=	100
D4	0	100	0	100	=	100
D5	0	0	100	100	=	100
	100	200	200			
	<=	<=	<=			
Limit of patient time for seeing doctor	200	200	200			

Another WBAN is chosen which uses fuzzy based decision making for assisting patients. Patients (1…. n) are connected to IoT Gateway. The patient in an emergency situation will get e-prescription immediately through fuzzy logic decision making unit.

A good use of medical resources by means of personalisation can lead to well-managed health services that can overcome the challenges of a rapidly increasing and aging population.

The membership function of the inputs and outputs are defined as follows:

- Distance (d in Km) Range [1 to 5] from dp1 to dp5
- Time (t in s) Range [5 to 25] from tp1 to tp5
- Cost (c in ₹) Range [40 to 100] from cp1 to cp5
- Available doctors

Range [1 to 5] denoted as less, medium and more

IF-THEN conditions are given as follows:

- IF((d = dp1) AND (t = tp1) AND (c = cp1), THEN less number of doctors will be available
- IF((d = dp2) AND (t = tp2) AND (c = cp2), THEN less number of doctors will be available
- IF((d = dp3) AND (t = tp3) AND (c = cp3), THEN medium number of doctors will be available
- IF((d = dp4) AND (t = tp4) AND (c = cp4), THEN more number of doctors will be available
- IF((d = dp5) AND (t = tp5) AND (c = cp5), THEN more number of doctors will be available

Depending upon the selection, the fuzzy inference system will give the specified output.

C. Integer Linear Programming

The Integer linear programming takes decisions according to the objective function and the constraints which are linear [20]. These linear models are summation of two or more decision variables and constraints. At first, the decision variables must be defined and next the constraints must be modeled with expressions. The objective function must be maximized or minimized according to the user. WBAN [21] is connected to the remote doctor with the help of IoT gateway.

Table 5. Distance, Time and Cost matrix assumed for patient and doctor

Distance (d in Km)	Patient			Time (t in s)	Patient			Cost (c in ₹)	Patient		
Doctor	P1	P2	P3	Doctor	P1	P2	P3	Doctor	P1	P2	P3
D1	5	8	6	D1	2	4	3	D1	100	60	40
D2	1	4	16	D2	1	2	10	D2	60	100	40
D3	4	1	7	D3	2	1	3	D3	40	60	100
D4	7	2	5	D4	3	1	2	D4	100	40	60
D5	13	7	1	D5	8	3	1	D5	40	100	60

The constraints are defined linearly; one is set equal to the doctor's available time in minutes and the other one restricts to be less than or equal to the time taken for the patient to wait as well as consult the doctor w.r.t the decision variables in Table 4.The distance of patient from doctor, the time taken to reach the doctor's place and the cost of consulting a doctor are taken as decision variables in Table 5. The doctors are denoted as D1, D2, D3, D4 and D5. The patients are denoted as P1, P2, and P3.

With the help of ILP, the patient can easily find the available doctor, his distance and his consultation fees. ILP results are obtained from [23].

V. CONCLUSION

In this paper, three efficient decision making strategies was presented for locating remote doctors by employing TOPSIS, ILP and fuzzy logic schemes. The proposed technique collects data through IoT to doctor. The doctor monitors the patient's details from a remote environment, aware the nurse in case of an emergency situation through IoT to nurse's PDA. The nurse with the help of doctor's e-prescription helps the patient to do the needful. IoT provides the opportunity to enable effective and timely medicine. This is a key task toward personalized healthcare system. The experimental results were based on various parameters (e.g., throughput, network lifetime, end-to-end delay, network models, objective function, fuzzy membership functions), showing the performance of the decision making schemes. A good use of medical resources by means of personalisation can lead to well-managed health services that can overcome the challenges of a rapidly increasing and aging population. This paper gives clear review of the model available for Body Area Networks with IoT. The proposed methodologies using different types of decision making systems will definitely help the patient in terms of real-time monitoring of his data through IoT. The governmental policies and regulations are required to ensure privacy during data transmission and storage, as well as during subsequent data analysis tasks, which must be taken into account.

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