
Proposed Conceptual IoT-Based Patient Monitoring Sensor for Predicting and Controlling Dengue

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**Noor Hafizah Hassan¹, Ely Salwana², Sulfeeza Md. Drus³, Nurazeen Maarop⁴,
Ganthan Narayana Samy⁵, Noor Azurati Ahmad⁶**

Abstract

Dengue is an epidemic-disease by mosquito-borne virus that spreads easily in geographically affected areas. Dengue outbreak management system has increasingly being developed in identifying and controlling the spread of dengue but with some limitation. The growing development of wearable Internet of Things (IoT), cloud computing, analytical approaches provide better alternative for dengue prediction and control. Previous literature collecting various parameters for analyzing dengue pattern. However, with the increasing number of analytical solution there is a need to investigate the high related parameters that should be use in analyzing and monitoring dengue outbreak before designing an IoT devices. Besides, there is a need for an alternative to ensure that early warning can be detected by monitoring the patient infected by the dengue, this paper aims to propose a conceptual IoT-based patient monitoring sensor for predicting and controlling dengue outbreak. Therefore, this paper provides a recent review of the latest methods and algorithms used to design wearable sensor for patient monitoring in dengue outbreak. Based on the review, this paper outlines the parameters that will be used in dengue for analyzing purposes. Finally, a conceptual IoT-based patient monitoring sensor were proposed comprising three different sensors to further work with analytical tools for dengue prediction pattern. The proposed conceptual design may help researcher to use the parameter identified for development of IoT sensor for dengue outbreak.

Keywords

Dengue Prediction, Internet of Things, Patient Monitoring Sensor, Medical Informatics

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^{1, 4, 5, 6} Advanced Informatics School, Universiti Teknologi Malaysia, Kuala Lumpur, Malaysia.

² Institute of Visual Informatics, Universiti Kebangsaan Malaysia, Bangi, Selangor, Malaysia.

³ CSIT, Universiti Tenaga Nasional, Selangor, Malaysia.

Corresponding author:

Email: noorhafizah.kl@utm.my



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Introduction

Dengue outbreak is increasingly high and has been grown rapidly and its outbreak results in acute illness that may lead to chronic phase. The rise of dengue incident reported has grown dramatically around the world for the last decades. In Malaysia, it has been reported from iDengue portal; a portal developed to show the outbreak of dengue that shows a total of 56,496 dengue cases was reported from 1st Jan to 25th July 2017. The actual spatial scale used in the models varied from community level to multi-country^[1]. In Thailand, socio-environmental changes have been identified as important determinants in the transmission of dengue. Spatial and temporal aspects of these changes have been increasingly incorporated into studies^[2].

Possibly infected users should be examined at an early stage of dengue so that they will not contributing in spreading the dengue infection. Though a number of on-going research efforts are focusing on various technical, economic, and social issues, many technical hurdles still need to be resolved in order to have flexible, reliable, secure, and power-efficient solution that is suitable for medical application. The evolution of IoT in healthcare application may enhance life quality specifically for dengue patient that need to be monitored. Currently, in another diseases the evolution of analytics in healthcare may help to predict heart disease risk and medications with the support of (Internet of Things) IoT based monitoring system^[3]. This concept can also be apply to predict and control dengue infections that adopt cloud computing and big data concept that capture daily healthcare related information using health data mining algorithm^[4]. The system can be used to find out the correlation between a health condition and lifestyle to provide early warning of dengue infections. Based on the environment of dengue epidemic discussed, this paper sought to identify climate or meteorological data and related clinical data influence on dengue outbreak in Malaysia. Therefore, a review of related literature on dengue and patient monitoring sensor were conducted. Then, a conceptual IoT-Based Patient Monitoring Sensor for Predicting and Controlling Dengue is proposed with identified parameters is presented.

Patient Monitoring Sensor

In a hospital or clinic, outfitting every patient with tiny, wearable wireless vital sign sensors would allow doctors, nurses and other caregivers to continuously monitor the status of their patients. In an emergency or disaster scenario, the same technology would enable medics to more effectively care for large numbers of casualties. First, responders could receive immediate notifications on any changes in patient status, such as respiratory failure or cardiac arrest. Technology assisted-growth shows that there is great variety running sensor reading vital signs such as blood pressure cuff, glucometer, heart rate monitor, including electrocardiograms, which allow patients to take their vital signs daily^[7]. The concept of IoT defined as the integration of all devices that connect to the network, which can be managed from the web and in turn provide information in real time, in order to allow interaction with people for the purpose of patient monitoring^[8].

The advancement of technology for improving quality of health care delivery have led towards the implementation of IoT in patient monitoring. Researchers across the world have started to explore various technological solutions to enhance healthcare provision in a manner that complements existing services by mobilizing the potential of the IoT. A number of work on IoT related for chronic disease monitoring system captured vital signs data via medical sensors, data mining algorithms to analyze the data and accessible by medical practitioner^[7,9]. However, this work only captures vital sign regardless of

environmental factors. The medical data transferred later can be adapt with big data analysis technologies to be used as guide in lifestyle, as a tool to support in the decision-making, and as a source of innovation in the evolving healthcare ecosystem^[10].

Related Works on Dengue

The infected cases dengue in Malaysia are reported on daily basis by the Ministry of Health (MOH), Malaysia and published online as in <http://idengue.remotesensing.gov.my/>. The web shows that increasing rate of dengue fever in Malaysia as of today's date. Recently,^[11] have reported the current status of dengue in Malaysia and proposed future development of vaccination and specifically stressed on the important of having a proper dengue control management to ensure that society understand the risk of this potentially global threat. In Malaysia, a study shows that the importance of detailed geographical analysis of dengue cases in heterogeneous environments with a focus on clustered populations at different spatial and temporal scales as an important step towards the development of an effective risk management strategy^[12]. Majority of the studies in Malaysia indicated an association between dengue, rainfall, and temperature^[13].

In Delhi, predictive analysis from^[14] shows that number of dengue cases are decreased during the period of maximum rainfall and cold temperature. These findings supported by^[15] in Indonesia, Malaysia^[16], and Vietnam^[17] that shows high temperature have a strong impact on dengue outbreak. In Pakistan, it also indicate that warming temperatures might extend the period of mosquito activity and the duration of disease transmission^[18]. Therefore, it can be concluded that climate are the important variables for the prediction of dengue cases. Besides the climate/environmental parameters, clinical record parameters are also important variable that influence dengue infection. A predictive model using decision trees classifications to detect dengue fever based on clinical history records of particular patient such as fever, fever duration, headache and related laboratory result has been proposed^[19] and improved the accuracies of prediction in dengue fever. Another work from^[20] use another two variables which are vital sign and blood profile of the dengue patients in dengue management practices for predicting and classify dengue patients. Clinical laboratory variables and patient characteristic can be used to distinguish patients with severe illness from those with mold dengue illness^[21]. The next sections describe body and environmental parameters that have been used in previous research for designing IoT wearable sensor. Environmental factor known as a risk factor such as humidity, sea surface temperature, geographical settings, temperature, precipitation, wind velocity, geographical settings, hygienic parameters, and socio environmental factors (population) were some of the factors related to dengue fever. Despite of predictive modeling on early detection of dengue fever, early work on developing a sensor to differentiate female Aedes mosquito through frequency differences^[22] has been proposed.

3.1 Body Parameters

The condition for dengue patients' body parameters need to be continuously monitored in any critical condition of plasma leakage in order to minimize the case fatality rate of dengue^[23]. A wireless continuous patient monitoring system for dengue may assist the monitoring process^[24]. Table 1 shows the related work on patient monitoring sensor.

Table 1. : Related Work on Patient Monitoring Sensor

Author	Wireless Technology	Sickness	Parameters
[25]	WSN	General Sickness	Movement characteristics, heartbeat, breath, proximity to other patients
[26]	WSN and AUR	General Sickness	Heart Rate, Temperature
[27]	Fog Computing, RFID, GPS	Chikungunya	Health related parameters
[28]	Bluetooth Technology	General Sickness	Patient Position, Glucometer, Temperature, Blood Pressure, Pulse-oximeter, Respiration, Galvanic Skin Response, ECG
[29]	Bluetooth, WI-If	Patient in ICU	blood pressure, heart beat rate, body temperature, body position
[30]	RFID	Chronic disease	Electrocardiogram (ECG) Glucose Sensor
[24]	Wireless Body Area Network	Dengue	Blood Pressure, Heart Rate, Temperature, Oxygen level

3.2 Environmental Parameters

Related literatures from 2012 to 2017 have been reviewed for identifying the parameters that are related on dengue outbreak as shown in Table 2. The table shows the earlier work on predicting dengue outbreak based on environmental or meteorological data.

Table 2. . Related Work on Environmental Parameters for Dengue

Authors	Methodology	Country	Parameters
[31]	Social Network Analytics	Worldwide	Dengue cases, Tweets on “Dengue”, “aedes” and “aegypti”,
[32]	Regression and Binning Classification	Thailand	rainfall, dengue cases, vegetation index & temperature , brightness temperature
[33]	K- Means Clustering	Selangor	temperature, rainfall and humidity
[34]	Delay Permutation Entropy	Hong Kong	Dengue Cases, Temperature, Rainfall, Sunshine, Wind Speed
[35]	ARIMA and ARIMAX model	Surabaya, Indonesia	Total dengue cases, dengue, demam berdarah, demam, dbd
[36]	Moderate resolution imaging spectroradiometer	Argentina	normalized difference vegetation index, land surface temperature, sum egg catches
[37]	Mathematical Model	Singapore	dengue cases, incubation period for human and mosquito
[38]	Gaussian Process	Brazil	Dengue cases, temperature, humidity
[39]	Statistical Analysis	Selangor	Dengue cases, land temperature, elevation
[14]	Linear Regression (R-tool)	India	Dengue cases
[15]	Granger causality	Vietnam	Dengue cases, temperatures, humidities, rainfall, hours of sunshine

Authors	Methodology	Country	Parameters
[40]	Artificial Neural Network	Philippine	Dengue cases, temperature, rainfall, humidity
[41]	C-Support Vector Classification	Taiwan	Year, Number of Week, Longitude, Latitude, Temperature, Precipitation
[16]	K-means clustering	Selangor, Malaysia	Dengue cases, notification id, year, coordinates, area, diagnosis, sub diagnosis
[42]	Moran's I, Average Nearest Neighbor, Kernel Density Estimation	Selangor, Malaysia	Location, dengue cases, date start and last case, period outbreak occurs, outbreak expected.
[17]	Regression model	Mekong Delta, Vietnam	Dengue cases, temperature, rainfall, humidity
[18]	Time-series models	Lahore, Pakistan	temperature, precipitation, humidity, dengue cases
[43]	Distributed lag non-linear models, Generalised estimating equation	Guangzhou china	temperatures, rainfall, average relative humidity, sunshine duration, and maximum wind velocity
[44]	Linear Regression	Yucatan, Mexico	Dengue cases, precipitation, maximum, temperature
[45]	Linear Regression	Dhaka city, Bangladesh	Dengue cases, temperature, rainfall, humidity
[46]	Fuzzy Association Rule Mining	Peru	Dengue cases, rainfall, temperature, and socio-economic data

Proposed Conceptual Design

Based on the review conducted, a proposed conceptual design comprises the sensors and parameters is presented in Figure 1. The sensor developed using WSN technology to sense and record vital signs and environmental parameters into cloud environment for analysis purposes. There are three type of sensor: Wearable Sensor–Body temperature, heart-beat, blood pressure,

Outdoor and Indoor Environment Sensor– Temperature, rainfall, humidity, air quality

Additionally, secure data storage in the cloud will be designed. When the medical records are outsourced to the cloud for storage, appropriate privacy preserving measures need to be taken to prevent unauthorized parties from accessing the information. Cloud computing will be incorporated in this monitoring system. Security concept such as public and private key encryption will be applied while developing the sensor. In the data collection layer, various healthcare data are collected by the data nodes and are transmitted to the cloud through the configurable adapters that provide the functionality to preprocess and encrypt the data. The data received from the sensor will be analyzed using data analytics tool for better understanding and efficient decision making in the descriptive and predictive context in monitoring dengue patients for healthcare management.

Figure 1 shows the proposed conceptual design for IoT-based Patient Monitoring Sensor for Dengue patients. It shows that three devices or sensors need to be installed in the patients house if any patients has been diagnosed with dengue. It has been proposed that the design comprises of three layers which are sensor layer, network layer and interface layer. Table 3 shows the summary of the possible criteria that can be choose to propose in achieving the design goals of the proposed IoT conceptual design. However, there are few challenges that need to be addressed in details in ensuring the success implementation of IoT in monitoring dengue outbreak.

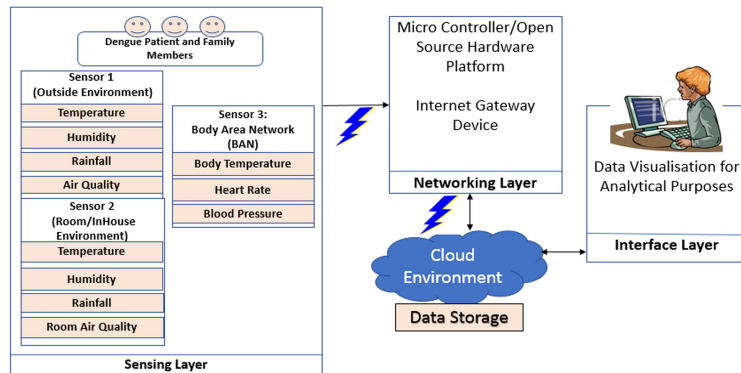


Figure 1. Proposed Conceptual Design of IoT-based Patient Monitoring Sensor for Dengue

Table 3. : Design Consideration for IoT devices

Design Goals	Criteria	Challenges
Communication Protocols (Sensing Layer to Network Layer)	ZigBee, Wi-Fi and Bluetooth	Acceptance, complexity, cost, data transmission security, privacy issues, data integrity and policy
Communication Protocols (Network Layer to Cloud Storage)	MQTT/CoAP/HTTP	Acceptance, complexity, cost, data transmission security, privacy issues, data integrity and policy
Microcontroller	Arduino/ Raspberry-Pi	Acceptance, complexity, cost, data transmission security, privacy issues, data integrity and policy
Energy Source	Main and Energy-Powered	Acceptance, complexity, cost, data transmission security, privacy issues, data integrity and policy
Latency	5minutes for data	Acceptance, complexity, cost, data transmission security, privacy issues, data integrity and policy
Storage	Cloud Storage	Acceptance, complexity, cost, data transmission security, privacy issues, data integrity and policy

Discussion and Conclusion

IoT in healthcare can decrease barriers for monitoring related health parameters, as well as avoiding unnecessary healthcare costs and efforts. Further, it also can provide right medical support for predicting and controlling dengue. Therefore, a proposed conceptual design called as an IoT-based patient monitoring sensor for predicting and controlling dengue has been presented with related parameters identified. Three sensors are proposed which are i) wearable sensor, ii) indoor sensor, iii) outdoor sensor. The identified parameters were chosen based on the reviews conducted on several previous related studies. The sensor will be able to collect physiological information and environmental data that uses gateway and cloud to analyze and store all the information that need to be sent to the medical officer. The

analyzed data will be used by the medical officer in healthcare organization for decision making purposes that can be further be visualized in dashboard to update the predictive factors and controlling the dengue outbreak. The limitation of this paper that it is not cover in depth the architectural elements of the IoT design that will be further investigated together with the challenges of implementing IoT in healthcare industry. Challenges such as acceptance, complexity, data transmission security and privacy issues needs to be highlighted further.

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