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DATA COLLECTION SYSTEM WITH SIGNAL OPTIMAL-ROUTINE FOR THE MINING AND ENVIRONMENTAL MONITORING IN VIETNAM

Purpose. To develop a data acquisition which is optimized for suitable purposes in monitoring/warning or decision-making assistance in the field of geography accident in mining activities or agroforestry.

Methodology. In activities related to mining, agroforestry and environmental monitoring, many climate factors must be taken into account including humidity, soil moisture or level of rainfall. Those data play a key role in pre-warning or assisting in decision-making for operators who are responsible for risk warning. In this paper, we present an optimized data acquisition system which is reasonable in cost, simple and easy in installation. The system includes a sensor station (SS) and a central station to collect data from specified monitoring points. The latter one is used to gather data from SS through a new and optimized LoRa WAN communication system. When sending gathered data to a cloud sever, an assistant system based on 3G module is established to warn of abnormal scenarios of the mining procedure or environmental parameters. The system is experimented, tested and implemented in the North Mountain area (Northwest) of Vietnam.

Findings. A development of an acquisition system with optimized-data for alarming/warning and monitoring in the field of geography accident, mining activities and environment. The system could get sensing signal in both direct way and indirect way despite of bad weather.

Originality. An improved Dijkstra algorithm is implemented to optimize and simulate the routing paths of a network. The optimization could show the best way for getting signal from sensor station indirectly to other ones, then to the central station.

Practical value. A simple, reasonable-cost and easy-installation system is formed for monitoring, risk warning in the field of geography, mining, and climate.

Keywords: *data acquisition, monitoring, LoRa WAN, risk warning, mining, optimization*

Introduction. Climate change has caused great damages and harms in recent years [1, 2]. Those damages include geological disasters, e. g., landslides, flood, drought, and saltwater intrusion, etc. The consequence of such disasters are negative disruptions to the community living. For example, many activities regarding traffic and agroforestry are disrupted, public buildings and private houses are ruined. In 2020, Vietnam recorded many very abnormal and extreme natural disasters. These natural disasters were categorized into 16 types. Specifically, nearly 50 cities and provinces in Vietnam were affected by nearly 300 storms and thunderstorms, tornadoes and heavy rain. In particular, several flooding (containing flash-flood) and landslides occurred due to heavy rain from October 6th to 22nd in the middle area of Vietnam [3].

As pointed in many research studies, an Early Warning System (EWS) can be an effective solution to alliviate the damage on communities caused by a natural disaster. Operating EWSs can help to mitigate damage by guiding citizens to take the appropriate actions at specific times when an intolerable natural hazard occurs [4]. Most of these research studies focused on developing a pre-warning or predicting the disasters caused by natural climate change [5, 6]. A lot of kinds of smart technology are utilized for implementing the notification or alert. Many of them are based on IoT and wireless-transferred signals [7–9]; however, most of them use sensors as the main component for control system. These sensors “collect data and sends to a central information, where data are processed and stored for intelligent decisions” [10]. The mentioned systems always contain detection platforms that perform sensing discipline base on: IoT, cloud of things, sensor web or sensor networks [10].

The EWSs consists of four key modules which are warning module, modelling module, setting module, and response one [10, 11]. All preliminary information including disaster types, warning areas, monitoring devices and data transmission system will be installed on the setting module of EWSs. The data transfer systems of EWSs have been developed with several wireless communication techniques. Among them, the LoRa technique, invented in 2009, is a network which allows data to

be transmitted for a long-range with low power consumption. For monitoring system, this technique has some advances in comparison to others. Low Power Wide Area Network (LP-WAN) technologies often utilize LoRa network to fill the gap between cellular networks, e. g., GSM, UMTS, and LTE (up to 100 km), and short range networks, e. g., Bluetooth, Wi-Fi, and ZigBee (0–1000 m). Also, LoRa network offers opportunities to meet the requirements for devices and applications of IoT [12]. Due to these advances, scenarios and applications including environmental monitoring, smart city, smart farming, and smart health care are witnessed using the design and implementation of LoRa [13]. Simultaneously, research to enhance LoRa network architecture for other applications has also been carried out. Likewise, research studies have also been done to implement LoRa network in EWSs, e. g., in [14, 15], LoRa network was proposed to be applied in a flood early warning system and a landslide early warning system. Nevertheless, these research studies focused on small area network and reasonable-cost sensor aspects.

In the paper, utilization of a LoRa network architecture is introduced for designing a data acquisition system to collect data in the North Mountain areas of Vietnam with the purpose of forecasting and alarming risks regarding natural disasters, monitoring the environment, studying climate change, as well as assisting agro-forestry decision making. The system could also be utilized for open-pit mining areas which are strongly affected by both raining level and the threat of landslide. The system is developed and the following advantages are obtained:

1. The system has sensor nodes at a distance of several kilometers from the receiving node and could operate well enough in comparing with imported system (which is developed by a famous branch company).

2. The transmission signal routines of the system are optimized to ensure that all data are collected directly (Sensor station (SS) to Central station (CS)) or indirectly (“blind” sensor station (SS) to other SS, then to CS).

Those advantages will be expressed in the next sections of the paper. The suitable solutions and the results proving the effectiveness of system will be verified in field of Middle of VietNam (Lai Chau Province, Phong Tho District, Ban Lang Ward).

Proposed system. System structure. It is well known that the Wireless sensor network (WSN) is popularly utilized for collecting data in EWSs [16]. There are two main groups of EWSs, namely the Territory EWSs (Te-EWSs) and the Local EWSs (Lo-EWSs). These two groups of EWSs differ from each other in terms of the area which the SWN supervises. For example, a Te-LEWS is used for a regional area such as a nation, a river catchment where multiple landslides can occur while a Lo-LEWS is associated with a local area in which a single landslide can take place [11].

By following the aforementioned classification, the data acquisition system used in this research is a Te-EWS because of several kilometers distance between receiving nodes and sensor. In addition, the mobile network signal (GSM) is adopted due to the long communication distance. Note that the GSM requires a large investment and that there is no GSM system in the northern area of Vietnam. To solve the above problem, in this paper, a solution depicted in Fig. 1, *a* is proposed. In this structure, each sensor station (SS) is installed in a monitoring place. A central station (CS) equipped with GSM signals receives signals from sensor stations. LoRa communication allows the CSs to collect data up to 20 kilometers far away. The data is then sent to the server by the CSs.

Stations' hardware. In addition to satisfying all technical requirements, the CS and the SSs have to be designed in a cost-effective way. LoRa communication is a promising solution that guarantees a remarkable cost reduction. Besides, the components of the CS and SSs have to be active and easy-to-find in Vietnam.

Fig. 2, *a* shows the structure of the SSs where a PIC16F886 is utilized. There are four sensors in each station, including a rainfall sensor, a soil moisture sensor, an air humidity sensor and an air temperature one. A 1-watt 10-km LoRa E32 433T30D module is used for the SSs. The system is powered by either a 12-V battery or a solar panel. The PCB of the SS is depicted in Fig. 2, *b*.

In the WSN system, the CS functions as a base node whose prototype is expressed in Fig. 3, *b*. A Raspberry Pi is used as the central controller. As already mentioned, the CS communicates with the SSs via a LoRa E32 433T30D module while a 3G sim module is used for communication of the server.

With the proposed designs, the costs of manufacturing for system are not very high (around 300 USD for CS and

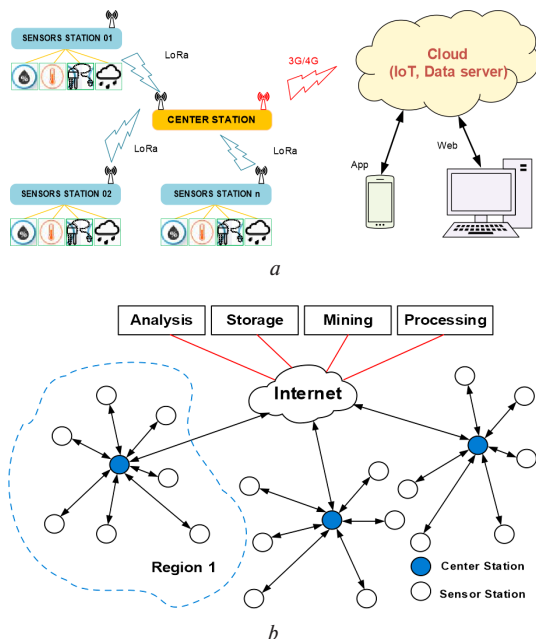


Fig. 1. Proposed system structure:
a – hardware structure of the system; *b* – data transmission between central station and sensor station through internet protocol

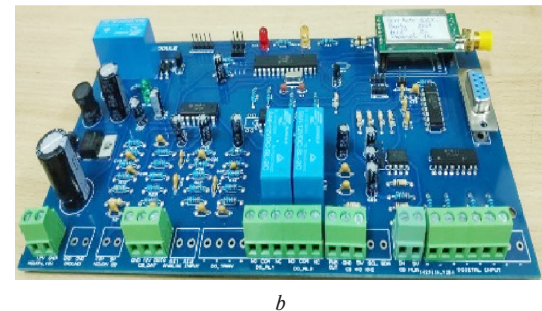
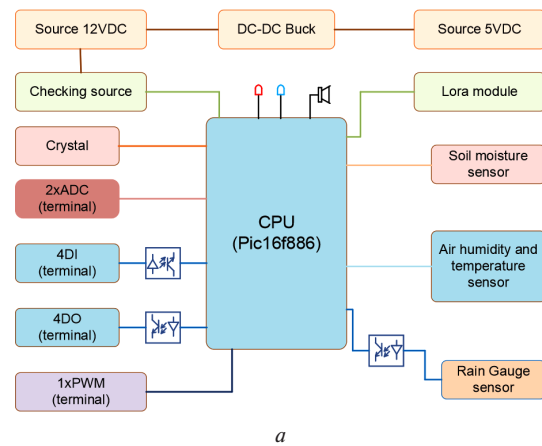


Fig. 2. Structure and PCB of Sensor station:
a – block diagram of SSs; *b* – realistic circuit board of sensor stations

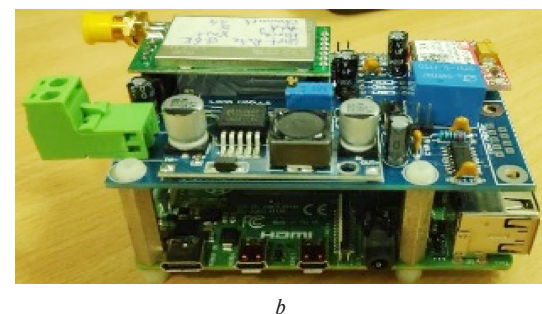
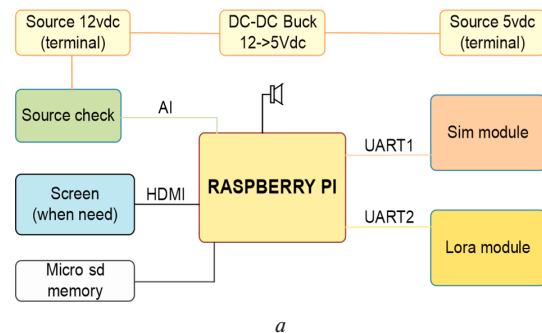


Fig. 3. Structure and PCB of Sensor station:
a – block diagram of central station; *b* – realistic circuit board of central stations

200 USD for SS). The product's prices are reasonable in comparison with other kinds of imported monitoring stations for air quality and weather.

Practical implementation and proposed communicating resolution. Field installation. In order to gather data regarding rainfall, soil moisture, temperature, and humidity in the Northern mountainous provinces of Vietnam, the area named Ban Lang Ward, Phong Tho District, Lai Chau Province in Vietnam is

chosen for testing. Fig. 4 shows the testing system including one CS and five SSs, being highlighted in the orange text and yellow text, respectively.

The Star Topology is applied to connect all stations. The CS works as a Base Station while the SSs operate as Sensor Nodes which are used to transmit data to the CS. The distances from one station to others can be directly determined via the Google map. As listed in Table 1, the maximum distance between the CS and SSs is 7.94 km which is an acceptable range of the chosen LoRa module; however, the links between them are often interrupted due to weak signals. Therefore, Mesh Topology along with a signal transmission algorithm were employed to solve this problem.

Routing Algorithm. The signal strength from one node to others is dependent on the distance between them. The obtained signal strength will be calculated with respect to distance as follows

$$L(f_s) = 32.45 + 20 \log(D) + 20 \log(f), \quad (1)$$

where $L(f_s)$ is the free space loss (dB); D is the distance between SSs and CS (km); f is the carrier frequency (MHz).

According to the literature of WSN, the Optimal Routing usually follows the shortest distance between stations. Nonetheless, the actual signal strength is also influenced by factors such as obstacles and weather condition in accordance with the Huygens Fresnel [16]. Thus, it is not suitable to optimize a routing path by distance for the rough mountainous areas. The routing path optimization is performed by transforming the Received Signal Strength Indication (RSSI) into the equivalent distance as follows [17]

$$RSSI(dBm) = -164 + Rssi, \quad (2)$$

where $RSSI$ is the loss (dB); $Rssi$ is $RSSI$ register value in the LoRa module.

Following (1 and 2), $RSSI$ values should be as calculated in Table 2. But in practice, $RSSI$ values read from the register of LoRa modules are depicted in Table 3.

In Table 3, some stations cannot communicate to each other despite being at a close distance. For example, CS cannot get data from SS01 because of a very weak signal (almost



Fig. 4. Station installations in Ban Lang Ward, Viet Nam

Table 1

Actual distances of stations (km)

S	CS	SS01	SS02	SS03	SS04	SS05
CS	0.00	2.10	4.29	0.15	1.29	4.10
SS01	2.10	0.00	3.45	2.40	3.63	6.35
SS02	4.29	3.45	0.00	4.11	2.87	7.94
SS03	0.15	2.40	4.11	0.00	1.34	4.29
SS04	1.29	3.63	2.87	1.34	0.00	5.16
SS05	4.10	6.35	7.94	4.29	5.16	0.00

no signal). To solve that problem, the optimization of routing path based on equivalent distance is implemented in the following paragraph.

Based on the received signal, from (1 and 2), the equivalent distance between stations is obtained as follows

$$D = 10^{\left(\frac{-196.45 + Rssi - 20 \log(f)}{20}\right)}. \quad (3)$$

The equivalent distances were calculated by a computer programming and a LoRa module after experiments are done at node positions. For each node, the testing computer communicates with the other nodes in order to record RSSI register values. Table 2 shows the actual test results of signal strengths. According to (3), the equivalent distances were computed based on RSSI register values, which are the second value in each cell of Table 2. The obtained equivalent distances, shown in Fig. 5, a, were then used for the optimization of communication routing path.

The aforementioned optimization was carried out based on an improved Dijkstra algorithm with the equivalent distances. The optimization are performed according to the following steps to obtain the expected output corresponding path [18].

- (1) Initialization: $num = 0$, $dist = +\infty$, $v[i] = 0$, ($i = 0, 1 \dots n$);
- (2) If $cost[s][i] \leq 1$, then set $v[i] = 1$, ($i = 0, 1 \dots n$);
- (3) If $v[r] = 1$, then $dist = cost[s][r]$, go to step (8); else go to step (4);
- (4) $\forall i \in \{v[i] = 1\}$, $u[num] = 1$, set $v[j] = 1$ when $j \in \{cost[u[num]][j] \leq 1\}$, ($j = 0, 1, \dots, n$);
- (5) If $v[r] \neq 1$, then $num++$, repeat step (4); else record the path that fulfills $v[r] = 1$,

$$dist[num] = cost[s][u[0]] + \sum_{j=0}^{num-1} cost[u[j]][u[j+1]] + cost[u[num]][r];$$

- (6) $num = num + 1$, repeat steps (4) and (5) until all the paths, that fulfill $v[r] = 1$, are obtained;
- (7) Set $dist = \min\{dist[i], i = 0, 1, \dots, num\}$
- (8) Output the corresponding path".

Where n is the number of nodes in the network; s is the sending node; r is the receiving node; l is the transmission radius limit; $u[num]$ is the relay node $[num]$ of a routing path; $v[i]$ is the visit mark (if not visited, set $v[i] = 0$; else set $v[i] = 1$); $cost[i][j]$ is the distance between node i and node j ; $dist$ is the distance corresponding to the optimal path from s to r .

Fig. 5, a shows the simulations of the network and the implementation of the above algorithm. The obtained optimal routing paths are highlighted in Fig. 5, b.

In Fig. 5, on the first phase, the central station (CS) was set up to communicate directly with the sensor stations (SS), shown by the black line links. These connections have poor reliability. The connection between CS and SS01 is often lost because the two stations are blocked by a hill in between. Communication between CS and the rest of the stations is more stable, but sometimes it also loses connection because of bad weather conditions. After using the equivalent distance map and Dijkstra algorithm, the CS has identified the communication to the SSs with the red links. As a result, communication between CS and SS01 has been established stably. The communication of the entire system is improved when the equivalent distance map and optimal path are updated periodically. Accordingly, every 2 hours, the CS will update the signal strength of the surrounding station to each SS station.

Results. The experimental data acquisition system were carried out and tested in Phong Tho district based on the suggested system structure, routing algorithm and network topology. The data was collected every 30 minutes. The data of temperature and air humidity obtained from five experimental sensor stations, which was recorded in the period from the 28th of January to the 15th of April, is shown in Fig. 6.

Table 2

RSSI calculated values

S	CS	SS01	SS02	SS03	SS04	SS05
CS	–	92	98	69	87	97
SS01	92	–	96	93	96	101
SS02	98	96	–	97	94	103
SS03	69	93	97	–	88	98
SS04	87	96	94	88	–	99
SS05	97	101	103	98	99	–

Table 3

RSSI value/Equivalent distance (km)

S	CS	SS01	SS02	SS03	SS04	SS05
CS	–	0/inf	103/7.78	65/0.1	98/4.38	105/9.80
SS01	0/inf	–	0/inf	0/inf	0/inf	104/8.73
SS02	103/7.7	0/inf	–	100/5.51	97/3.90	104/8.73
SS03	65/0.10	0/inf	100/5.51	–	95/3.10	103/7.78
SS04	98/4.38	0/inf	97/3.90	95/3.10	–	106/10.99
SS05	105/9.80	104/8.73	104/8.73	103/7.78	106/10.99	–

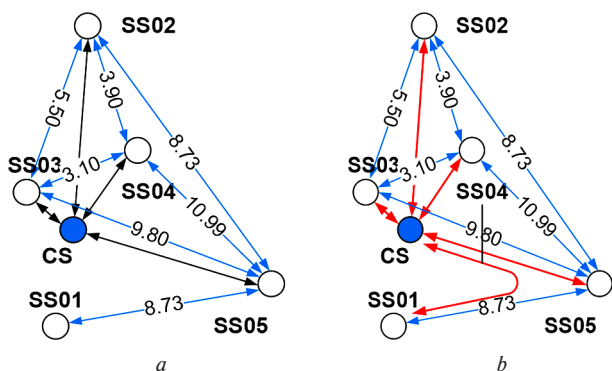
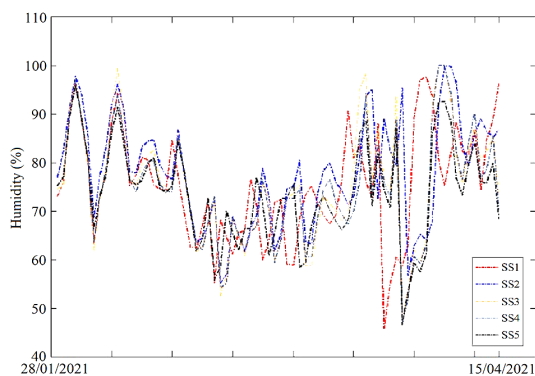


Fig. 5. Communication optimal routing path

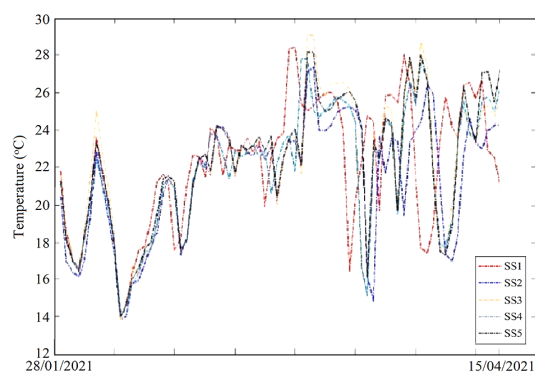
The graphs indicate that the data can be collected without interruption (there is no sudden changes in value) in the over two months. The testing results on field-site show that the suggested system has met the technical requirement of the project CT2019.01.06. The system including hardware and software can operate effectively and collect data from SSs with the longest distance of 7.94 km.

Data collection shown in proved the effectiveness of the suggested system. By utilizing the data transferring protocol that uses 3G signals, the values of temperature and humidity are continuously collected and transmitted to the CS. In the interval from the 28th of January to the 15th of April (2021), within small area but long distance, the measurements are unique.

Conclusions. The paper presented the performance of collecting parameters of temperature, soil moisture, air humidity, and precipitation in Ban Lang Ward. The collected data is used for monitoring, territorial warning/alarmed of geography disasters and supporting decision making. The Lora technique, the suitable hardware and an optimal routing path has solved practical problem of connection loss caused by weak signals. The Test results presented the efficiency of the proposed topology and optimal routing path, which is based on the equivalent distance. Therefore, this system is capable of collecting data and transmitting stably to the center station. The optimal routing path has been carried out online by measuring the network mapping signal strength continuously. The practical application of the proposed system should be ex-



a



b

Fig. 6. Data collected from five sensor stations: a – temperature; b – humidity

panded in the field of mining, climate monitoring or pre-warning the natural disasters such as landslides or flash-flood. For better applications, other technologies like AI or big-data analysis should be incorporated with the system by utilizing collected data as input.

The proposed system has strong specification parameters in comparing with commercial and international systems. Moreover, the optimization of routine could fix the problem of signal disconnection between CS and some SS. In bad conditions (foggy or hard rain fall), some SSs could work as trans-

mitters to transfer data to CS for continuous collection of expected measuring values. In some ways, it fixed the disadvantages of GSM/GPRS based system [21].

The advantages of this system has been proved by testing in very strong affected area, therefore applying the system largely for monitoring or pre-alerting the risk of landslide in open-pit mines should be considered.

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Система збору даних з оптимальним режимом сигналу для моніторингу гірничих робіт і стану навколишнього середовища у В'єтнамі

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Мета. Розробити процедуру збору даних, що оптимізована для відповідних цілей моніторингу/попередження або допомоги у прийнятті рішень у галузі розташування аварійних ситуацій при гірничодобувній діяльності або в агролісництві.

Методика. У діяльності, пов'язаній із видобутком корисних копалин, агролісництвом і моніторингом навколишнього середовища, необхідно враховувати багато кліматичних факторів, включаючи вологість, вологість ґрунту або кількість опадів. Ці дані відіграють ключову роль під час попереднього сповіщення або допомоги у прийнятті рішень операторам, які відповідають за попередження про ризики. У цій роботі ми представляємо оптимізовану систему збору даних, що є розумною за вартістю, простою й легкою в установці. Система включає сенсорну станцію (СС) і центральну станцію для збору даних із заданих точок моніторингу. Остання використовується для забору даних із СС через нову та оптимізовану систему зв'язку LoRa WAN. При відправленні зібраних даних на хмарний сервер створюється допоміжна система на основі модуля 3G для попередження про аномальні сценарії проведення гірничих робіт або про параметри навколишнього середовища. Система пройшла випробування, тестування та впроваджена у Північному гірському районі (північний захід) В'єтнаму.

Результати. Розробка системи збору даних з оптимізованими даними для сигналізації/попередження й моніторингу в області місцезнаходження аварійних ситуацій, гірничих робіт і навколишнього середовища. Система могла отримувати сигнал як прямим, так і опосередкованим шляхом, попри погану погоду.

Наукова новизна. Реалізовано покращений алгоритм Дейкстри для оптимізації й моделювання шляхів маршрутизації в мережі. Оптимізація може показати найкращий спосіб передачі сигналу опосередковано через сенсорну станцію іншим станціям, потім центральній станції.

Практична значимість. Сформована проста, недорога й легка в установці система моніторингу, попередження ризиків у сфері проблем розташування на місцевості, видобутку корисних копалин і клімату.

Ключові слова: збір даних, моніторинг, LoRa WAN, попередження про ризики, гірничі роботи, оптимізація

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