Application of Wireless Sensor Networks Technology for Early Forest Fire Warning

Tran Cong Hung, Pham Minh Tan, Huynh Trong Thua

***Abstract*—this paper is demonstrating ways to create a system that track the changes of heat and humidity to quickly predict a forest fire by using wireless sensor networks. The whole hierarchy of sensor node was routing for the improve PEGASIS way to prevent the power loss of basic PEGASIS and increase the longevity of the whole network. The forest fire warning detect the changes of nature, help prevent forest fire that effect the life of man.**

***Index Terms*—Wireless Sensor Network (WSNs), Forest Fire, humidity, temperature, PEGASIS improve**

I. INTRODUCTION

Forest play an important role in man's life and man's resources, it also involve in the evolution of society and balancing the ecosystem of earth. However, because of the uncontrollable act of man and the unpredictable of nature therefore forest fire is a common thing. It is the most devastating disaster of forest resources and the life of man.

In recent years, the frequency of forest fire is rapidly increase due to climate changes, man impact and other smaller element. The mission to prevent and control the forest fire has become the most interested in any forest fire preventing organization. As of now, the common method is patrol the wood, watching from the tower and in recent years is to use satellite images.

Although watching from the tower is easy and possible, it's has disadvantages. First thing is that this require a lot of financing, material and experience worker. Secondly, a lot of problem is concerning the staff such as not being present at the watch tower or not capable of watching in real time and the range of supervising is very limited. The satellite system supervising is also have flaw, due to some element it's limited the efficiency of the method. For example it only scan a handful of cycle and the resolution is very low. Another problem is that cloud can block the feed of the satellite camera, making it more difficult to calculate the changes [1].

The wireless sensor networks comprised of small sensor nodes, it consume less energy, communicate through the wireless connection, and has the task of sensing, measurement, calculation that aim to collect, converge data to make a global decisions about the natural environment [2].

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A sensor node is composed of four basic components: Sensors, processor unit, transceiver unit and power supply unit. In addition, they also have the additional components applications such as navigation systems, power generator and mobile managing [3].

Because of the rapid development of wireless sensor networks and the shortcoming of traditional monitoring in forest fire prevention, the need for a better and more efficiency way to prevent forest fire form happening.

As mentioned before, because of the energy consumption problem that exist in the PEGASIS basic protocol. We propose an innovative solutions to PEGASIS basic protocol system is to have it dividing the regions, each region forming a chain and choosing a master node to transmit data to the "mobile SINK". The contents of this paper are as follows: Part I introduction, introduces the status quo of forest fire warnings. Part II related works, introduces the limited issue of basic PEGASIS protocol and propose the improving PEGASIS. Part III simulate and evaluate the results. Part IV hardware and software design, and then the conclution and future development.

II. RELATED WORKS

a. Basic PEGASIS [4]

The PEGASIS protocol is based on the almost optimal sequence and is an improvement compared with LEACH. Protocol PEGASIS resolve cost issues arise during the formation of clusters LEACH through the construction of string node as illustrated in pic 1. The construction chain comply by greedy algorithm. Each node will select the nearest neighboring node as the next jump in the chain structure. After forming the chain, rather than maintain the information about the cluster and cluster members, each node just have to track the next adjacent node and the one before it. The process of communication in the chain is performed sequentially. Each node in the chain will gather data from its neighboring node until all the data is gathered at the beginning of the string node. The beginning node control the order of communication process between the nodes in sequence.

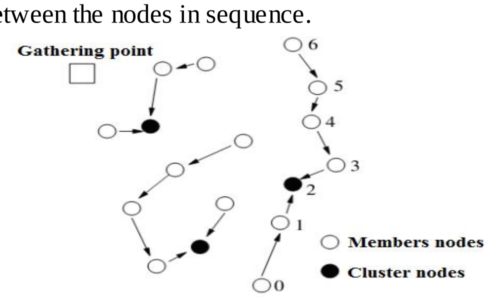


Fig. 1. The structure of chain PEGASIS

An example of the communication process in the chain are shown in Fig. 1. The first node in this example is node number 2. Firstly, node 2 send notice to node 0 to initiate the communication process. Node 0 sends its data to node 1. Node 1 will aggregate this data with data of itself to generate a data message has the same length. This will be transmitted to node 2. After node 2 receives the data from node 1, node 2 sends a notice to the other end of the string (node 6). Information from node 6,5,4,3 will also be synthesized and sent to node 2. After receiving information aggregated in the chain, node 2 will sends this information to the collection point via a single jump.

The PEGASIS protocol provides more engergy efficiency than protocols LEACH. This is due to the reduced cost of energy in the chain communication. However PEGASIS protocol has greater latency than LEACH because the data must be transmitted sequentially and the beginning node must wait until all the messages has received before communicate with the collection point. In addition, the PEGASIS protocol required all the information in the chain must be aggregated into a single thread. This can cause inaccuracies in the information sent to the collection point.

b. PEGASIS improve

In PEGASIS basic algorithm, we found out that although the power has been shared among the nodes, but still reamain some limitation:

- The node that remotely far away from BS station will likely consume more energy and thus rapidly died.
- The delay in the network is quite sizable, especially if the network is large then the chain will be very long, thus a very high number of hops needed to transmit data from the end to the base station.
- Additionally, the nodes in the chain must recognize the configuration of the network and this is not always easy for sensor networks.
- Another issue is the bottlenecks at the main nodes. Meaning that, when the data reach the main node then there are no more power to transmitted to the BS station.

c. Solution

- To overcome the latency, we can divide the network into several sub-regions, each region will set up a chain.
- In every sub-regions we'll have one sink with unlimited energy source and is capable of moving across different sub-regions.

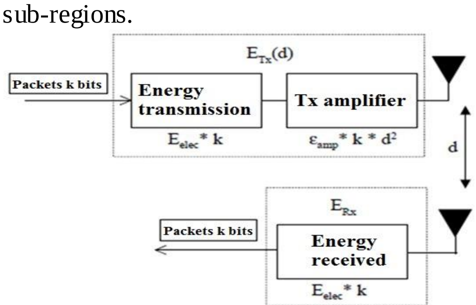


Fig. 2. A simple energy model

- Corresponding to each substring there will be a master node. These master nodes will send the data gathered to the respective sink.

d. The energy model

Communicate the data k bit at a d distance using a cordless model.

$E_{Tx-elec}$: energy / bit transmission

$E_{RX-elec}$: energy / bit received

ε_{amp}: factor of the amplifier

The transmission equation:

$$E_{Tx}(k,d) = E_{Tx-elec}(k) + E_{Tx-amp}(k,d) \quad (1)$$

$$E_{Tx}(k,d) = E_{elec} * k + \varepsilon_{amp} * k * d^2$$

Equation party:

$$E_{Rx}(k) = E_{Rx-elec}(k) \quad (2)$$

$$E_{Rx}(k) = E_{elec} * k$$

The receiving of the data also cost a relatively high energy, so we need to maximize the number of transmit and receive in each node.

d. Building the multi chains:

The chain construction procedures is like the routing protocols of PEGASIS basic, in this proposal has 4 strings are formed as follows:

- Sink send the "hello packets" to all nodes to get the information of all the nodes.
- Sink find the farthest node by comparing the distances of all nodes to it in the first sector.
- Formation of a sequence starting from the farthest node, this is the root node of the chain, and the root node will search for nearest node to incuded it in the chain.
- Then each node find the path to the nearest node that doesnt connected in the chain, then connect to it with a similar approach.
- In the sequence, each node i receives data from node j, operating as a parent node to node j, in the meantime node j act as a child node to node i.

The same process create the repeating chains in all four areas and therefore 4 strings are created.

e. Chosing the master node in the chain

In this section, string chose the master node on the basis of densit Q assigned to each node. Each node calculate its density Q by dividing its remaining energy to its distance from the base station, and then compare the proportion Q of all nodes in the chain. The node that has the largest Q will be chosen as the master node of the main chain. After forming a chain, each node i will calculates its distance (*dp*) with the parent node and then compare that distance with the distance from it to sink (*dbs*) . If (*dp*) >(*dbs*) then node i acts as a leading node and sen the gathered data to sink instead of sen it to parent node.

$$Q_i = E_i / D_i \qquad (3)$$

E_i: The remaining energy of node i

D_i: Distance from node i to sink

f. Moblie sink

In this simulation, assumes that sink has the capable of holding unlimited energy and its mobility is used to maximize the lifetime of the network. Sink move within the network in a fixed orbit, from one region to another and wait in a temporary location. In this period, sink remain still and receive data from all nodes of the chain. The "sojourn location: act as a temporary sink staying as for data collecting. In the algorithm the proposed staying location are: (33m, 25m,), (33m,75m), (66m, 25m) and (66m, 75m).

g. Proposed algorithm for mobile sink

In this part we offer a scalable algorithms for distance limitaions of sink to solve these problem above. Is consists of three steps: Calculated the profile lenth of staying first. Then based on the length of staying, sink started to mobile by identifying the place to be is (33m, 25m), (33m, 75m), (66m, 25m) and (66m, 75m) all bounded to a specific requirement as before. In the third step of the algorithm is to calculate the total length of a staying in a ring. The total length of stay of 4 places within 1 circle is as follows:

$$T_s = \sum_{i=1}^{4} (t_i) \qquad (4)$$

In this *Ts* is the total length of stay of a ring. The first objectives is to improve the lifetime of the network by increasing the total length of stay, while second target is to ensure the consistency of data transmission between the sink and the master node of the chain. So the problem is to maximize:

$$\sum_{i=1}^{4} (t_i) \qquad (5)$$

Depend on:

$$x_{ij} = \begin{cases} D & \text{if } i = j \\ 0 & \text{if } i \neq j \end{cases} \qquad (6)$$

In which *Xij* is measured in bits between master node and sink with potential sites i and j, 1 ≤ i, j ≥ 4. D is the total data transfer between the master node and sink in the time of staying. Potential placements depend on four unchanged areas. The master node of the chain transmitted the data to sink is also at a specific staying location.

III. THE SIMULATION AND EVALUATION OF RESULTS

As for this section we are going to be using the MATLAB language to simulate a network of 100m x 100m. The simulation scenario consists of 100 nodes were randomized to 25 in four different areas. Sink move in the center position of each region forming one closed loop. The simulation parameters are as follows:

+ Network size: 100m x 100m
+ Number of nodes: 100
+ Place residence: (33m, 25m), (33m, 75m), (66m, 25m), (66m, 75m)
+ Energy's initial nodes: 0,5J
+ Packet size: 2000 bít
+ Place station BS: (0m, 0m)
+ Numbe of simulate loop: 5000

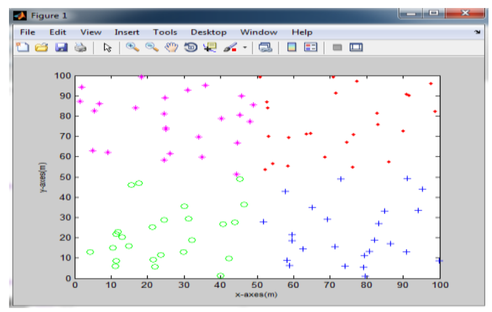


Fig. 3. Layout the network into 4 random area

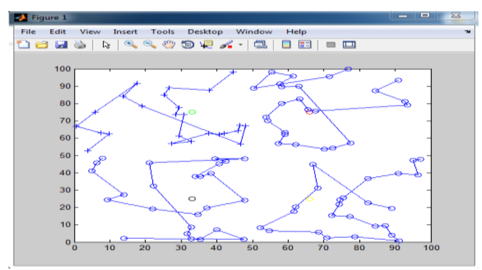


Fig. 4. The network of nodes is sending the data in chain while the nodes is still active

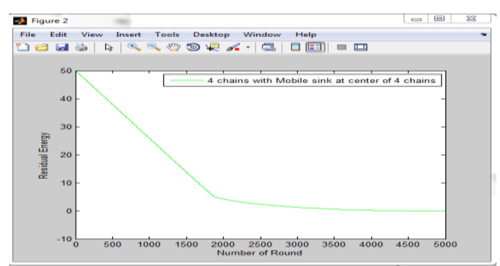


Fig. 5. Chart of the remaining energy of all nodes

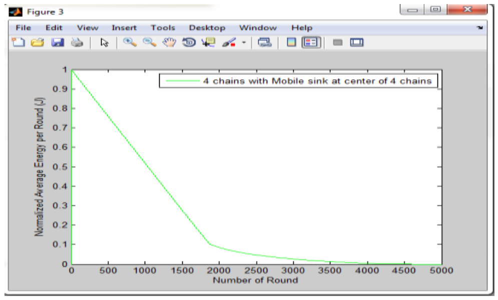


Fig. 6. Graph of the average energy of nodes per ring

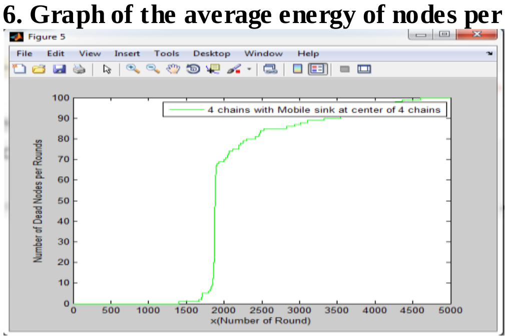


Fig. 7. Graph of nodes die each ring

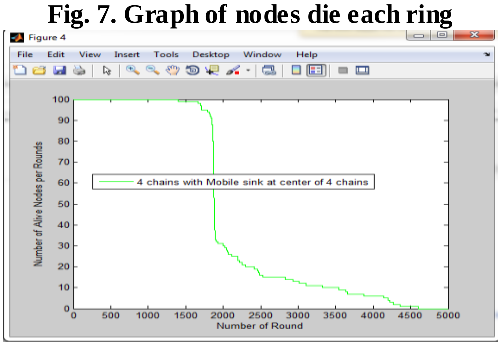


Fig. 8. The graph of active nodes per ring

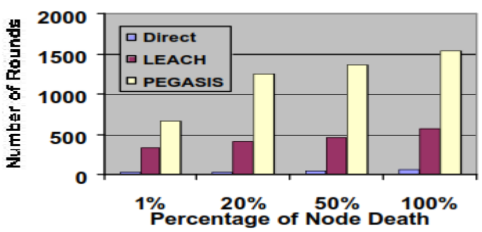


Fig. 9. Graph of percentage of node die in the ring [5]

Base on the result of page [5] compared with the simulation results, we see that nodes start dying in PEGASIS in just about 675 rings. While in PEGASIS multi-series, node only start dying when reached ring 1400. When the whole network die, all the node is empty by the time reaching ring 1544 in PEGASIS, while in PEGASIS multi-series, the nodes only die when ring 4615 is reached.

Through that we see the lifetime of the network under PEGASIS multi-series is significantly improve, compared to the previous routing protocols like LEACH, PEGASIS. So it is very suitable to build a network of "early warning system for forest fires".

IV. DESIGN THE HARDWARE AND SOFTWARE

a. The whole systematic of the model

Building a forest fire early warning network sensor include circuit design data acquisition from temperature sensors, humidity data transmitted to the master circuit node via wireless and will be transmitted through gateways next to the computer display. This computer will acts as a server, can be monitored remotely via another computer (as a client) in the internet.

Based on the reference page [6] [7] we propose the model system of early warning of forest fires are as follows:

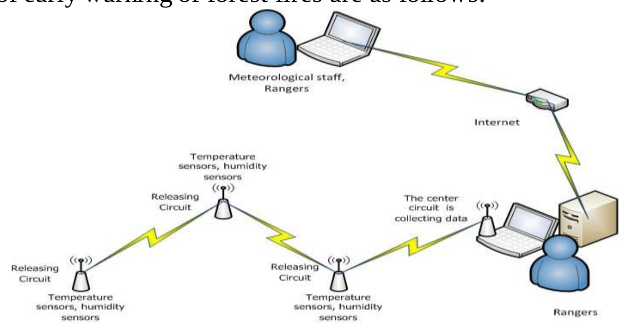


Fig. 10. Diagram of the whole system

The software was program to connect to the hardware through the network. Data collected will be handled in software, then the system will issue a warning (lights, speaker) when the parameter exceeds a certain level sensor.

b. Hardware Design

Based on the reference of page [8] we proposed the hardware design as follows:

- *Detailed circuit block diagram*

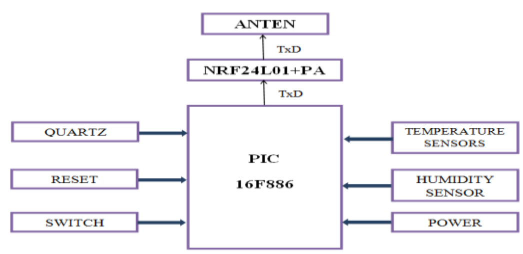


Fig. 11. Diagram of the releasing circuit

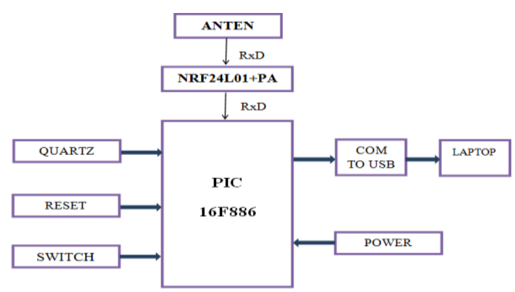


Fig. 12. Diagram of the receive circuit

Blocks function:

- Quartz block: oscillators for PIC16F886.

- Reset block: Connect the reset pins of the PIC in order to restart the PIC.

- Keypress block: The function keys help start and stop the operation of the system.

- Power Module: Provides a stable power supply for the PIC and the equipment on board.

- The sensor block includes temperature, humidity sensor that aquire data from the environment to give to PIC to analyze.

- Transceiver block nRF24L01 + PA and antennas: transmit and receive signal via radio wave.

- Computers: Receive signal from the motherboard, put the data on computer analysis and processing.

- *Central control circuit*

4

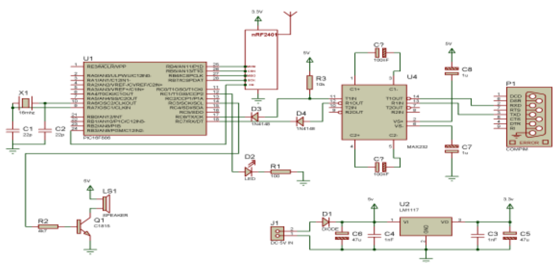


Fig. 13. The central controllering circuit

- *Releasing circuit, signal relays*

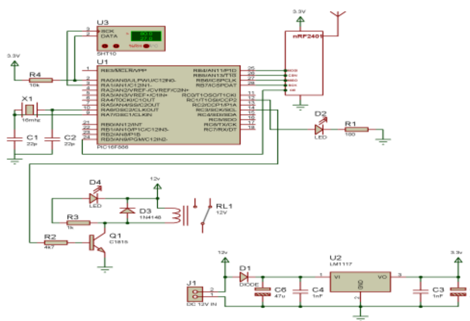


Fig. 14. The releasing circuit, signal relays

- *Actual results*

The system consists of two types of circuits:

+ Circuits that has tempature and humidity sensors are distribution in the forest network to tranfer data back to center. The cirvuit system is 9v battery powered.

Fig. 15. The releasing Circuit is sending the parameters to the central circuit

Fig. 16. Releasing Circuit is turn on the control relays

+ The motherboard circuit will collect the data that sent by the circuit at the ranger station, mounted forest fire warning equipment (lights, speaker).

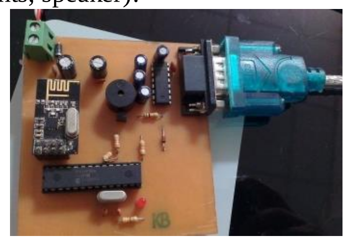


Fig. 17. The center circuit is collecting data that associated with the computer

c. The software

Based on the reference page [9] we decided to design and analysis the software by VB6, using TeeChart charting, we designed the interface is as follows:

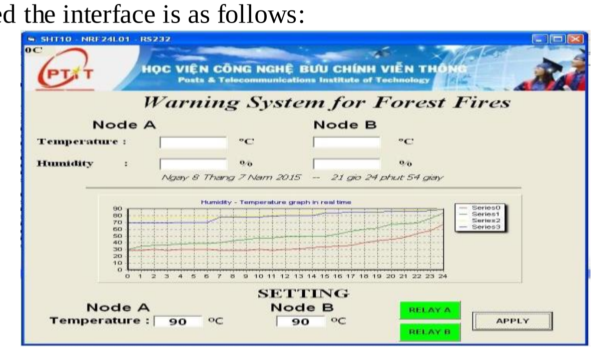


Fig. 18. The interface of the program

The program includes the textbox to display the results of temperature and humidity of the sensor device in real time. All information received from the sensors are displayed on this interface.

After the design is finished, conducting measurements and observe the parameters obtained from sensors we get the following results:

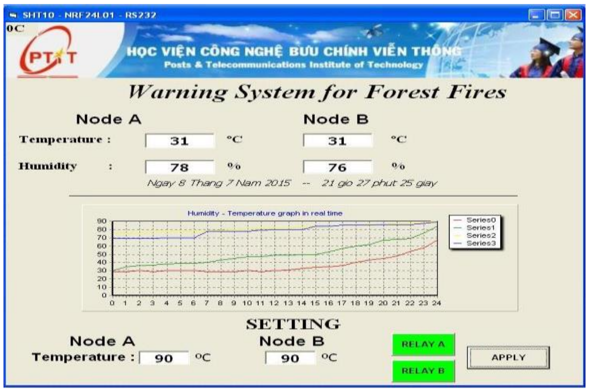
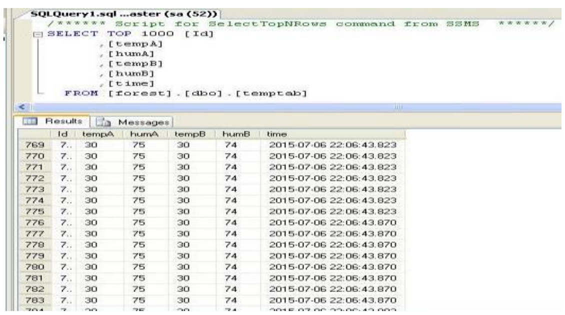


Fig. 19. Result of running the program



SQLQuery1.sql ...aster (sa (52))

```
/******* Script for SelectTopNRows command from SSMS  *******/
SELECT TOP 1000 [Id]
      ,[tempA]
      ,[humA]
      ,[tempB]
      ,[humB]
      ,[time]
  FROM [forest].[dbo].[temptab]
```

Results | Messages

	Id	tempA	humA	tempB	humB	time
769	7..	30	75	30	74	2015-07-06 22:06:43.823
770	7..	30	75	30	74	2015-07-06 22:06:43.823
771	7..	30	75	30	74	2015-07-06 22:06:43.823
772	7..	30	75	30	74	2015-07-06 22:06:43.823
773	7..	30	75	30	74	2015-07-06 22:06:43.823
774	7..	30	75	30	74	2015-07-06 22:06:43.823
775	7..	30	75	30	74	2015-07-06 22:06:43.823
776	7..	30	75	30	74	2015-07-06 22:06:43.870
777	7..	30	75	30	74	2015-07-06 22:06:43.870
778	7..	30	75	30	74	2015-07-06 22:06:43.870
779	7..	30	75	30	74	2015-07-06 22:06:43.870
780	7..	30	75	30	74	2015-07-06 22:06:43.870
781	7..	30	75	30	74	2015-07-06 22:06:43.870
782	7..	30	75	30	74	2015-07-06 22:06:43.870
783	7..	30	75	30	74	2015-07-06 22:06:43.870

Fig. 20. The results stored in the database

The signals received from the sensor is included in the play circuit PIC16F886 and wirelessly transmitted to the receiver circuit PIC 16F886 and then transmitted to the computer, the computer acts as a server in the network, we can monitored from the client over the network. The signals collected will be displayed simultaneously on both the server and client, in the image above is the signal we receive from the environment: temperature 31 ° C, humidity 77%. To know the result of the environment changing, we influence in the sensor using a cigarette lighter close to the recommended temperature sensors, blown into the humidity sensor and the result will be displayed on the screen.

V. CONCLUSION

This paper has studied the broadest definition of sensor networks, routing protocols often used in sensor networks, research and proposed routing protocol Pegasis multithreading. Building a successful signal acquisition system from the external environment through sensors that use wireless networking, network stable performance and the parameters collected on the sensor is relatively accurate.

In future studies continue routing protocols for sensor networks, channel quality testing and troubleshooting on the transmission line, using the position sensors and the GIS technology. Giving the energy saving solution for sensor nodes, reducing the cost of products to be applied in practice.

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