

Early Fire Detection with WSN

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Abstract – Wireless Sensor Networks (WSNs) are rapidly emerging as a potential networking technology for usage in various emergency situations. WSNs offer capability to locally and collaboratively sense and interpret collected data from the environment and, correspondingly, react to various situations. This paper presents a small scale WSN testbed for early fire detection. The testbed comprises wireless sensor nodes – Sun SPOTs, different additional sensors and appropriate accessories which provide real time monitoring of the environmental parameters and on-time notification system. The testbed serves as a proof-of-concept and is further extendable for many different applications and outdoor settings.

Key words – Fire, Sensors, Sun SPOT, Testbed, WSN.

I. INTRODUCTION

THE world witnesses disasters of various magnitudes caused by global warming, different social and political movements, natural catastrophes etc. These phenomena, if uncontrolled, can cause significant damages to natural and human resources. For example, in August 2003, a forest fire was initiated by lightning a strike in the Okanagan Mountain Park in the Province of British Columbia, Canada. The estimation showed that 25 912 hectares were affected by the fire and 239 homes were burned [1]. Furthermore, in Macedonia, during the summer 2007, around 400 fires affected 70 000 ha of forest causing €32 million material losses. Fires also have serious economic implications such as destruction of habitats, forest and material damage, costs of fire-fighting etc. Because of these destruction issues, prevention and efficient monitoring of fires has become a global concern.

Wireless Sensor Networks (WSNs) lately provide means to observe hazardous phenomena. They represent wireless networks of spatially distributed sensor nodes used for monitoring different physical phenomena and parameters and transferring the data in real time to the data acquisition center for additional processing. Owing to these characteristics, WSNs are emerging as a novel and efficient concept for fires forecasting and detecting. They constitute a promising framework for building near real-time fire detection systems.

This paper presents a demo platform, as a proof-of-concept, for WSN based early fire detection system. The testbed consists of wireless sensor modules – Sun SPOTs,

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different sensors, a server and a GSM/GPRS gateway. The idea of the demo realization is to provide remote real time monitoring of environmental parameters of interest, detect possible fire and send fire alarm reports to the responsible departments.

The rest of the paper is organized as follows. Section II describes the scenario for early fire detection, the basic idea and the developed algorithms. Section III analyzes the performed experiments. Finally, section IV concludes the paper.

II. TESTBED FOR EARLY FIRE DETECTION

This section elaborates on a small scale demo setup for early fire detection using WSN.

A. Scenario Description

The scenario setup consists of Sun SPOTs [6], four types of sensors and a base station forming a WSN, MySQL database hosted on a server, GPS/GPRS gateway and web application - GUI. The demo platform utilizes 3 Sun SPOTs, 3 temperature/humidity sensors, 3 carbon dioxide and 1 wind speed sensor. These sensors can measure the key parameters which indicate fire occurrence and the possibility of fire spreading.

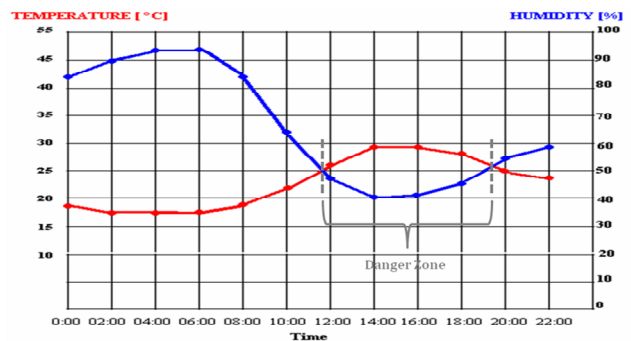


Fig. 1. Relation between humidity and temperature obtained with daily measurements

The measurements of the daily temperature and humidity variations in Fig. 1 show that the time interval when a fire can occur (when the value of the temperature is higher than the humidity) is between 12 and 19 hour. In other words, when the weather is dry and hot, a fire can occur with higher probability. This information is used as an input value for the development of corresponding algorithms for fire detection in the testbed.

Fig. 2 depicts the scenario and the testbed architecture which is further elaborated in details.

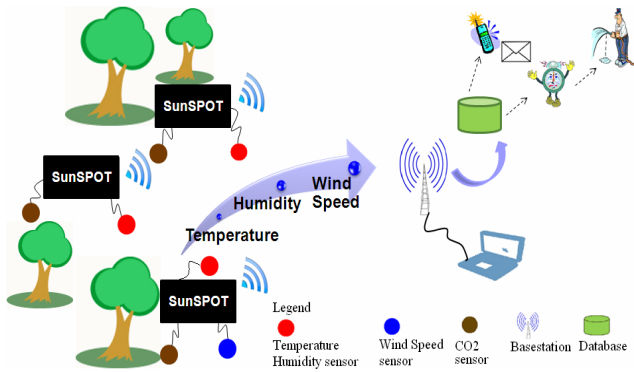


Fig. 2. Testbed architecture

The demo is formed of 3 sensor boards, Sun SPOTs, which are placed in a triangle and connected to a laptop. Temperature/humidity and CO2 sensors are attached to 2 of the 3 available Sun SPOTs, and the third Sun SPOT has temperature/humidity, CO2 and wind speed sensor attached to it. The base station is connected through USB cable to a laptop. The task of the attached sensors is to sense the environment and to measure the appropriate parameters of interest. Since the Sun SPOTs are the only programmable devices used in this scenario, an application is developed to define several situations which describe the fire danger. The application includes algorithms which use the measured parameters' values. Those algorithms define whether it is a dangerous situation or not according to some previously determined parameters' thresholds. A part of the code which runs on the Sun SPOTs and indicates an alarm situation is presented in Fig. 3.

```

1. If temperature > 45 °C &&
2. If humidity < 60 % &&
3. If CO2 particles > 500 ppm →
4. print ("Risk/Alarm situation")
5. Broadcast (temperature, humidity, wind speed values,
Sun SPOT address )

```

Fig. 3. Pseudo code for alarm situation in the algorithm run on the Sun SPOTs

The algorithm applied on Sun SPOTs operates in the following manner. If the defined thresholds are achieved, the broadcast messages are sent by the Sun SPOTs using ZigBee radio technology. The Sun SPOT broadcasts a string with the values of the measured temperature, humidity and wind speed and SPOT's address. The concentration of CO2 is only monitored and used as an indicator of a fire. The base station (Sun SPOT without sensor board) collects these values and afterwards forwards them to the database. Another program runs on the server which uses the database values and forms a neighbour list. The neighbour list is based on a predefined topology of the Sun SPOTs. The algorithm works in a way

that if there are two neighboring Sun SPOTs that have detected the same conditions presented in Fig. 3, an SMS is sent to a mobile phone of a responsible person as a notification for the possible fire. The neighboring algorithm is developed to facilitate prevention of false fire alarms, requiring at least two neighbor node's fire confirmation.

The GUI has the possibility to display the real time values of the measured parameters (temperature, humidity, and wind speed), possible alarm notifications, and also the ID of the appropriate Sun SPOT. It further allows acquiring daily and weekly graphs of the temperature alteration.

B. Equipment Overview

The equipment for the demo realization is chosen accordingly to the key parameters that need to be observed. The HS-2000V temperature/humidity sensor is presented in Fig. 4a [3]. This sensor has two analog outputs, one temperature and one humidity and it needs 5V supply voltage in order to work properly. This supply voltage is provided by the Sun SPOTs' batteries.

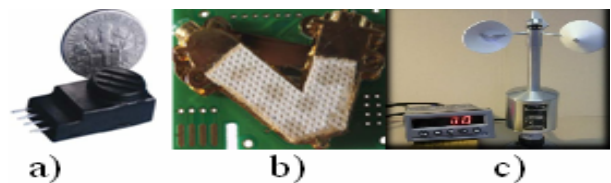


Fig. 4. a) HS-2000V temperature/humidity sensor b) MH-Z11 CO2 sensor c) A100L2 anemometer

MH-Z11 CO2 sensor, based on NDIR technology, is used (see Fig. 4b) for measuring the amount of carbon dioxide particles in the air [4]. The required supply voltage for the proper functioning of this sensor is 4.5 – 5.5V. An external 4.5V battery is used to enable its functioning since the maximal current drawn that a Sun SPOT can support is 150mA and the maximal current that can be drawn by the MH-Z11 sensor is 120mA. So, if the supply voltage from the Sun SPOT is used there is a possibility of damaging the Sun SPOT.

The sensor for the wind speed measurements is the anemometer - A100L2, presented in Fig. 4c [5]. It requires supply voltage of 6.5 – 28V and it works attached to external 9V battery.

III. DEMO APPLICATION AND PERFORMANCES

This section presents the analysis performed with the demo application. The 3 Sun SPOTs are positioned in a way so that each Sun SPOT is a neighbor of the other two SPOTs. The temperature/humidity sensor of the Sun SPOT with address 0014.4F01.0000.6839 is warmed up, and the second one - with address 0014.4F01.0000.664C, is unaffected. Under these circumstances, the Sun SPOT with address 0014.4F01.0000.664C displays a message "Normal Situation" and the Sun SPOT with address 0014.4F01.0000.6839 - message "High temperature" on the console window where the applications are run. Fig. 5

and Fig. 6 depict the results given by these 2 Sun SPOTs.

```

C:\WINDOWS\system32\cmd.exe - ant run
175;
[Ljava] Normal situation
[Ljava]
[Ljava]
[Ljava] SunSPOT_ID:          BSLight:          BSTemperature(C):          BSTilt:
Temperature(C):          Humidity(%):          Wind (m/s):          Smoke (ppm):
[Ljava] 0014.4F01.0000.664C;          730;          49.25;          0;          -0.013
426423200859293;          29.0;          73.0;          0;
171;
[Ljava]
[Ljava]
[Ljava] SunSPOT_ID:          BSLight:          BSTemperature(C):          BSTilt:
Temperature(C):          Humidity(%):          Wind (m/s):          Smoke (ppm):
[Ljava] 0014.4F01.0000.664C;          726;          49.25;          0;          -0.013
426423200859293;          29.0;          73.0;          0;
171;
[Ljava] Normal situation
[Ljava]
[Ljava]
[Ljava] SunSPOT_ID:          BSLight:          BSTemperature(C):          BSTilt:
Temperature(C):          Humidity(%):          Wind (m/s):          Smoke (ppm):
[Ljava] 0014.4F01.0000.664C;          730;          49.25;          0;          -0.018
79699248120301;          30.0;          73.0;          0;
195;

```

Fig. 5. Results from 0014.4F01.0000.664C

```

C:\WINDOWS\system32\cmd.exe - ant run
146;
[Ljava] High temperature
[Ljava]
[Ljava]
[Ljava] SunSPOT_ID:          BSLight:          BSTemperature(C):          BSTilt:
Temperature(C):          Humidity(%):          Wind (m/s):          Smoke (ppm):
[Ljava] 0014.4F01.0000.6839;          723;          30.75;          18;          0.0456
49838882921595;          37.0;          80.0;          18;
146;
[Ljava]
[Ljava]
[Ljava] SunSPOT_ID:          BSLight:          BSTemperature(C):          BSTilt:
Temperature(C):          Humidity(%):          Wind (m/s):          Smoke (ppm):
[Ljava] 0014.4F01.0000.6839;          676;          31.0;          0.04564
9838882921595;          37.0;          80.0;          18;
146;
[Ljava] High temperature
[Ljava]
[Ljava]
[Ljava] SunSPOT_ID:          BSLight:          BSTemperature(C):          BSTilt:
Temperature(C):          Humidity(%):          Wind (m/s):          Smoke (ppm):
[Ljava] 0014.4F01.0000.6839;          665;          31.0;          0.04564
9838882921595;          39.0;          78.0;          17;
141;

```

Fig. 6. Results from 0014.4F01.0000.6839

With continuous warming, the temperature/humidity sensors of the two Sun SPOTs, .664C and .6839, and with increasing the number of carbon dioxide particles in the air above 500 ppm, the conditions needed for activating the broadcast action are fulfilled. The thresholds are achieved by the 2 Sun SPOTs, so the algorithm enters a loop of broadcasting the measured values. Fig. 7 and Fig. 8 depict the results obtained by the 2 Sun SPOTs after the environmental conditions were changed.

```

C:\WINDOWS\system32\cmd.exe - ant run
[Ljava]
[Ljava]
[Ljava] SunSPOT_ID:          BSLight:          BSTemperature(C):          BSTilt:
Temperature(C):          Humidity(%):          Wind (m/s):          Smoke (ppm):
[Ljava] 0014.4F01.0000.6839;          125;          37.25;          4;          0.9532
768472610097;          58.0;          19.0;          1;
659;
[Ljava] Broadcast is going through
[Ljava] Alarm situation
[Ljava]
[Ljava]
[Ljava] SunSPOT_ID:          BSLight:          BSTemperature(C):          BSTilt:
Temperature(C):          Humidity(%):          Wind (m/s):          Smoke (ppm):
[Ljava] 0014.4F01.0000.6839;          76;          37.75;          4;          0.94790
5477980666;          58.0;          19.0;          4;          67
9;
[Ljava] Broadcast is going through
[Ljava] Alarm situation
[Ljava]
[Ljava]

```

Fig. 7. Results from 0014.4F01.0000.6839

```

C:\WINDOWS\system32\cmd.exe - ant run
[Ljava] Risk region
[Ljava]
[Ljava]
[Ljava] SunSPOT_ID:          BSLight:          BSTemperature(C):          BSTilt:
Temperature(C):          Humidity(%):          Wind (m/s):          Smoke (ppm):
[Ljava] 0014.4F01.0000.664C;          97;          36.25;          0;          0.94790
5477980666;          48.0;          17.0;          0;          41
73;
[Ljava]
[Ljava]
[Ljava] SunSPOT_ID:          BSLight:          BSTemperature(C):          BSTilt:
Temperature(C):          Humidity(%):          Wind (m/s):          Smoke (ppm):
[Ljava] 0014.4F01.0000.664C;          101;          36.5;          0;          0.94790
5477980666;          48.0;          18.0;          0;          42
27;
[Ljava] Broadcast is going through
[Ljava] Risk region

```

Fig. 8. Results from 0014.4F01.0000.664C

Fig. 7 shows that the Sun SPOT with address .6839 has measured a temperature of 58 °C, the humidity is 19%, the wind speed is 1 m/s (afterwards is 4m/s) and the level of smoke is 659 particles per million. Thus, the conditions which define alarm situation are satisfied and Sun SPOT starts broadcasting. The second Sun SPOT (.664C) is also in a risk region and it broadcasts its parameters to the BS.

Since broadcast messages are sent to the BS under these circumstances, the BS collects these values and sends them to the database. These results are stored in the database in this manner:

Sender:	Temperature[°C]:	Humidity[%]:	WindSpeed[m/s]:
0014.4F01.0000.664C;	48.0;	17.0;	0.0;
0014.4F01.0000.5B59;	50.0;	46.0;	0.0;
0014.4F01.0000.6839;	58.0;	19.0;	1.0;

Given that there are 2 neighboring Sun SPOTs which have overcome the thresholds, the server's application sends an SMS alert as a fire alarm. The form of the SMS is presented in Fig. 9.



Fig. 9. SMS for fire alarm

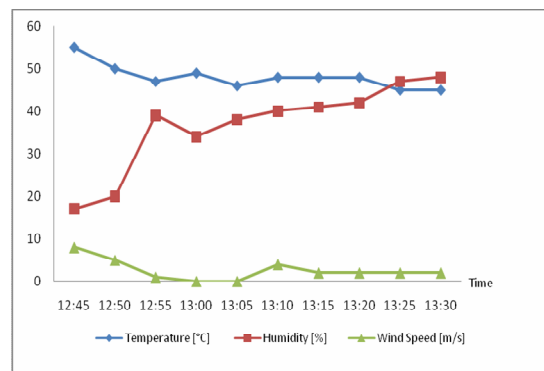


Fig. 10 - The values of the Sun SPOT 0014.4F01.0000.6839 parameters over time Besides these results, a graph for the temperature,

humidity and wind speed variations over time can be extracted from the values stored in the database. Fig. 10 depicts the results of the performed experiment. It shows that the conditions for fire occurrence and the greatest risk of its spreading were measured at 12:45pm. Also, the reverse proportion of humidity and temperature is noticeable.

IV. CONCLUSIONS AND FUTURE WORK

This paper proposed a WSN based testbed for early fire detection. The demo platform measures four key parameters which are used as an input in the developed algorithms for the application realization. Based on the parameters' values and the implemented algorithms, in a case of detected "fire" conditions the appropriate alert (e.g. SMS) is sent to authorities.

Since the developed platform is a small scale demo setup, the complete realization for more advanced outdoor implementation requires further enhancement. The energy supply is a key factor for the WSN lifetime in an outdoor environment. Since batteries have limited lifetime, an implementation of a different energy harvesting devices (e.g. solar) can be considered for future work.

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