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An Benchmark Improved Approach to Detect Forest Fire in Early Stage and to Predict the Spread Direction Using Wireless Sensor Network

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Abstract: Wireless Sensor Networks (WSNs) have attracted the attention of many researchers. Wireless Sensor Networks (WSNs) are used for various applications and wild fire detection is one of them. Since numerous sensors are usually deployed on remote and inaccessible places, the deployment and maintenance should be easy and scalable. Wireless sensor network consists of large number of small nodes. The nodes then sense environmental changes and report them to other nodes over flexible network architecture. Sensor nodes are great for deployment in hostile environments or over large geographical areas.

Keywords: WSN, LEACH, Geographical Areas.

PROBLEM STATEMENT

The wireless sensor networks (WSN) is one of the most significant technologies in the 21st century. In recent years, achievements in micro-sensor technology and low-power electronics make WSN become realities in applications. In this Project, we propose a system for WSN based on environmental monitoring. The system can monitor several environmental parameters such as underground water level, barometric pressure, ambient temperature, atmospheric humidity, gas and smoke detector and provide various convenient services for end users who can manage the data via a internet from long-distance or applications in console terminal. Through the use of WSN in the environmental monitoring, it's possible to change the traditionally environmental monitoring methods for people.

LITERATURE REVIEW

Title of Paper: An Acknowledgement based System for Forest Fire Detection via LEACH Algorithm

Author: Shruti Gupta, Lekha Doshi Publication: IEEE 2017

This paper presents an acknowledgement based system for disaster management by utilizing wireless sensor network, which sense the environmental change and based on that communicate between the nodes. For the communication purpose, Low Energy Adaptive Clustering Hierarchy (LEACH) algorithm has been used. The LEACH algorithm is hierarchical in nature and therefore, helps in maintaining connection among the nodes, which leads to effective communication. Disaster is an activity, which can occur anytime and anywhere without prior information, which affects the whole mankind, human, animal and their prosperity. Since, disaster is a natural activity, no one can stop it, but a system can be developed to alert the people before the occurrence, so that many lives can be saved. The focus of this paper is towards utilizing the sensor network and LEACH algorithm for the development of an alert system, which works on the temperature. A threshold based mechanism is used to save the energy that is the system

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works only when the temperature reaches to its threshold value otherwise do not waste the energy by routing the data continuously.

The key issue with this approach is over energy consumption since the proposed model sense temperature after every fifteen minutes.

There are challenges are broken-down into the list of sequences.

1. Satellites are used to detect the disaster, but after its initiation.
2. Network lifetime effects on the cost of the project.

Whenever the temperature rises more than the threshold value sensors senses this information and pass it to base stations through LEACH Low Energy Adaptive Clustering Hierarchy algorithm. It passes a message to the radio station via a base station. Each node has a capability to sense the data and route it forward to cluster head and cluster head forward this data to its nearby the base station

The head of node communicates with all other nodes with the help of LEACH. Each node is diverse in nature that means they have many and different capabilities to sense different environment characteristics like temperature, pressure, humidity All nodes doing their sensing but pass the data to head nod when the temperature increase by threshold value.

A. Work at Physical layer - At physical layer provides discretization and convert the analog values in digital values. After that digital values are passed to data link layer.
B. Work at data link layer (MAC Layer) - Data link layer received the digital bits from the physical layer and passed to the network layer. This layer acts as interface to the network layer in experimental work. Serial communication is provided at this layer to transfer the bits. This layer also provides the functionality of continual check of the connection between the nodes and the radio receiver.
C. Work at network layer -Network layer provide routing to the reach the packets .In experiments LEACH algorithms are used to route the data. LEACH algorithm selects the head node each head node makes the communication with other nodes. This layer received the data and its forward them to application layer, i.e. user channel through which user receives the data and able to know that disaster would be occur.

Title of Paper: Wireless Sensor Networks for Early Detection of Forest Fires

Author: Mohamed Hefeeda, Majid Bagheri Publication: IEEE

This paper present the design and evaluation of a wireless sensor network for early detection of forest fires. Author first presents the key aspects in modeling forest fires. Author do this by analyzing the Fire Weather Index (FWI) System, and show how its different components can be used in designing efficient fire detection systems.

The FWI System is one of the most comprehensive forest fire danger rating systems in North America, and it is backed by several decades of forestry research. The analysis of the FWI System could be of interest in its own right to researchers working in the sensor network area and to sensor manufacturers who can optimize the communication and sensing modules of their products to better fit forest fire detection systems.

Then, author model the forest fire detection problem as a k-coverage problem in wireless sensor networks. In addition, author presents a simple data aggregation scheme based on the FWI System. This data aggregation scheme significantly prolongs the network lifetime, because it only delivers the data that is of interest to the application. We validate several aspects of our design using simulation. In this paper, we present the design and evaluation of a wireless sensor network for early detection of forest fires. Our design is based on solid forestry research conducted by the Canadian Forest Service over several decades.

The Fire Weather Index System.

Author proposes calculation of fire indexes according to the FWI System at cell heads where the data is more likely to be correlated. This removes the need for communicating all sensor data to the sink. In our system, only a few aggregated indexes are reported to reduce energy consumption.

Author use the Fire Weather Index (FWI) System developed by the Canadian Forest Service (CFS) [, which is based on several decades of forestry research. The FWI System estimates the moisture content of three different fuel classes using weather observations. These estimates are then used to generate a set of indicators showing fire ignition potential, fire intensity, and fuel consumption.

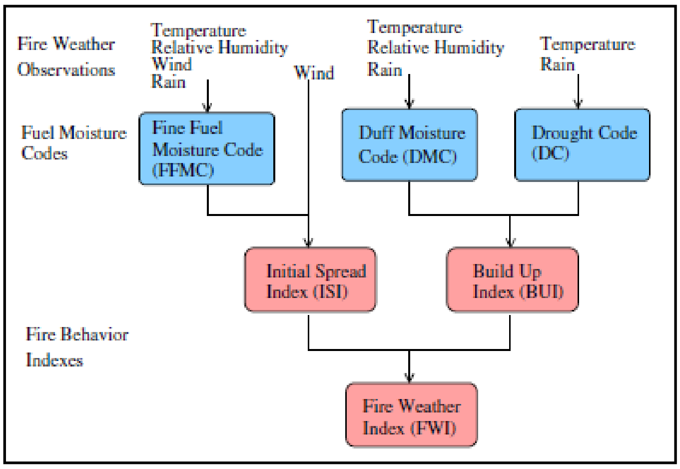


Figure: The Fire Weather Index System

As shown in Figure, the FWI System is comprised of six components: three fuel codes and three fire indexes. The three fuel codes represent the moisture content of the organic soil layers of forest floor, whereas the three fire indexes describe the behavior of fire. Author briefly describe these codes and indexes. There are three fuel codes in the FWI System: Fine Fuel Moisture Code (FFMC), Duff Moisture Code (DMC), and Drought Code (DC). FFMC represents the moisture content of litter and fine fuels, 1–2 cm deep. Since fires usually start and spread in fine fuels, FFMC can be used to indicate ease of ignition, or ignition probability

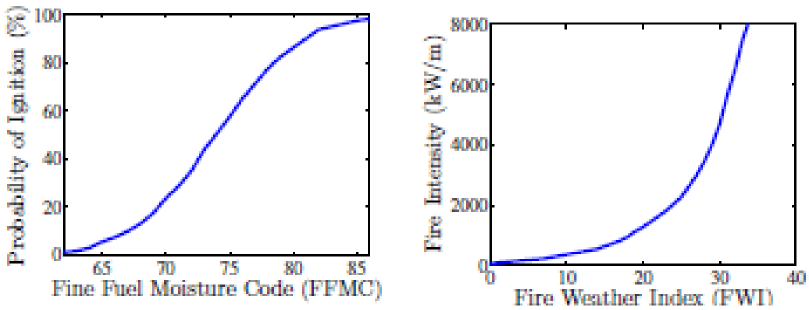
The Duff Moisture Code (DMC) represents the moisture content of loosely compacted, decomposing organic matter, 5–10 cm deep. The DMC determines the probability of fire ignition due to lightning and also shows the rate of fuel consumption in moderate depth layers. The last fuel moisture code, the Drought Code (DC), is an indicator of the moisture content of the deep layer of compacted organic matter, 10–20 cm deep. The DC is indicative of long-term moisture conditions, determines fire's resistance to extinguishing, and indicates fuel consumption in deep layers. There are three fire indexes: Initial Spread Index (ISI), Buildup Index (BUI), and Fire Weather Index (FWI). As indicated by Fig. 1, ISI and BUI are intermediate indexes and are used to compute the FWI index. The ISI index indicates the rate of fire spread immediately after ignition. It combines FFMC and wind speed to predict the expected rate of fire spread. The BUI index is a weighted combination of the DMC and DC codes, and it indicates the total amount of fuel available for combustion. The FWI index indicates fire intensity by combining the rate of fire spread with the amount of fuel being consumed. Fire intensity is defined as the energy output measured in kilowatts per meter of flame length at the head of a fire. The head of a fire is the portion of a fire edge showing the greatest rate of spread and fire intensity.

There are two goals of the proposed wireless sensor network for forest fires:

1. Provide early warning of a potential forest fire.
2. Estimate the scale and intensity of the fire if it materializes.

Both goals are needed to decide on required measures to combat a forest fire. To achieve these goals, we design our sensor network based on the two main components of the FWI System: (i) the Fine Fuel Moisture Code (FFMC), and (ii) the Fire Weather Index (FWI). The FFMC code is used to achieve the first goal and the FWI index is used to achieve the second. In the following, we justify the choice of these two components by collecting and analyzing data from several forestry research publications. The FFMC indicates the relative ease of ignition and flammability of fine fuels due to exposure to extreme heat. To show this, we interpolate data from to plot the probability of ignition as a function of FFMC. The results are shown in Figure (a). The FFMC scale ranges from 0–101 and is the only component of the FWI System without an open-ended scale. Generally, fires begin to ignite at FFMC values around 70, and the maximum probable value that will ever be achieved is 96 . Low values of FFMC are not likely to be fires and can simply be ignored, while larger values indicate more alarming situations. The FWI index estimates the fire intensity by combining the rate of fire spread (from the Initial Spread Index, ISI) with the amount of fuel being consumed (from the Buildup Index, BUI). A high value of the FWI index indicates that in case of fire ignition, the fire would be difficult to control. This intuition is backed up by several studies. For example, the study in relates the fire intensity with the FWI index. Author plot this relationship in Figure (b) by interpolating data from. Both the FFMC code and the FWI index are computed from four basic weather conditions: temperature, relative humidity, precipitation, and wind speed. These weather conditions can be measured by sensors deployed in the forest.

The accuracy and the distribution of the sensors impact the accuracy of the FFMC code and the FWI index. Therefore, we need to quantify the impact of these weather conditions on FFMC and FWI. Using this quantification, we can design our wireless sensor network to produce the desired accuracy in FFMC and FWI. To do this, we contacted the Canadian Forest Service to obtain the closed-form equations that describe the dependence of FFMC and FWI on the weather conditions. Author were given access to these equations as well as a program that computes them. Author used this program to study the sensitivity of FFMC and FWI to air temperature and relative humidity.



(a) Prob. of ignition vs. FFMC (b) Fire intensity vs. FWI

A sample of results is presented in Figure(c), which shows the sensitivity of FWI to temperature for fixed wind speed at 5 km/h and precipitation level of 5 mm. Author use these results to bound the errors in estimating FFMC and FWI in the next section.

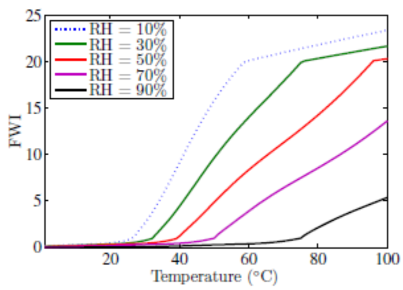


Figure (c) Sensitivity of the FWI Index to temperature

Modeling Forest Fire Detection as a K-Coverage Problem.

Author present the design of a wireless sensor network for forest fire detection. Author start by modeling the forest fire detection problem as a *k*-coverage problem also extend our distributed *k*-coverage algorithm in to address several issues relevant to forest fire detection.

Author periodically compute FFMC and FWI for each cell. This information is then forwarded—through multi hop routing—to a processing center for possible actions. Recall that FFMC and FWI are computed from basic weather conditions such as temperature and humidity. To be useful in detecting fires and assessing their intensity, FFMC and FWI need to be estimated within specific error bounds. For example, if the error in the estimated FWI is high (e.g. 5 units), the fire would be misclassified. To achieve the desired accuracy in FFMC and FWI, basic weather conditions should, in turn, be measured accurately.

The accuracy level of measuring basic weather conditions is determined from the curves relating FWI and FFMC to weather conditions. For instance, the worst-case slope of the FWI-Temperature curve in Figure (c) at RH = 10% is about 0.62. Thus, an error up to 1 unit in FWI requires measuring the temperature with 1.6 degree accuracy. Knowing the needed accuracy in measuring weather conditions, author design our sensor network to collect data with that accuracy. Author illustrate this design using temperature as an example, the same can be done for other metrics. Consider measuring the temperature in an arbitrary cell. Author take a number of samples from the cell to estimate the actual temperature. Each sample is collected by a sensor. Multiple samples are needed because of potential errors in readings of sensors. Many factors contribute to such errors, including: different environment conditions, inaccurate calibration of sensors, aging of sensors, and unequal battery levels in sensors. Let us define a random variable T as the reading of a sensor inside the cell. It is reasonable to assume that T follows a normal distribution because of the several factors mentioned above, which all are stochastic in nature.

We denote the mean and standard deviation of T as μT and σT, respectively. The estimated mean $\_\mu T$, also known as the sample mean, is given by:

$$\widehat{\mu}_T = \frac{1}{k}\sum_{i=1}^{k} t_i,$$

Where tis are the individual sensor readings, and k is the number of samples. As the number of samples increases, the sample mean becomes closer to the actual mean. The error between the sample mean and the population mean is given by,

$$k = (\frac{z_{\frac{\alpha}{2}}\sigma_T}{\delta_T})^2.$$

Where z is the standard normal distribution, α is the length of the confidence interval, σT is the population standard deviation, and k is the sample size. $z\alpha 2$ can be derived from the table of standard normal distribution.

Thus, given a confidence value of $100(1-\alpha)\%$ and standard deviation of σT , we can determine the sample size required to estimate the population mean μT within δT error margin. σT can be calculated from the specifications of the sensing board. The error in sensor measurements is usually interpreted as $2\sigma T$. Since each temperature sample is collected by a sensor, we need to have at least k active sensors to cover a cell, i.e., the cell is said to be k-covered. To illustrate, suppose we want to measure the temperature in a cell with a maximum error of 1◦C and with a confidence value of 95%. Assume that sensors have temperature sensing boards with an error up to 2◦C, i.e., σT = 1. Therefore, we need a coverage degree k = (1.96 × 1/1)2 = 4. In the evaluation section, we study and validate the relationship between the coverage degree k and the error in FFMC and FWI.

Keeping k sensors active in a cell all the time will make these sensors die quickly and the sensor network lifetime will be much smaller than even a single fire season (4–6 months). To prolong network lifetime, more sensors need to be deployed and the monitoring task is rotated among them. When sensors are deployed randomly and in high density, the coverage of the cell can be approximated by the coverage of all sensor locations. That is, point coverage is a good approximation for area coverage in dense sensor networks. Now, there is need to activate a subset of sensors to ensure k-coverage, while other sensors are put in sleep mode to conserve energy. A issue that was not addressed by the algorithm in is data aggregation and processing. More specifically, author need to compute FFMC and FWI for each cell. To achieve this, we assign each cell a head, which collects weather conditions from other nodes in the cell and computes FFMC and FWI. The assignment of cell heads is done in a distributed manner. Cell heads carry out significant load, because they compute FFMC and FWI from complicated equations and participate in data forwarding across cells. Hence, unless the role of the cell head is rotated, heads run out of energy and die earlier than other nodes. This may cause coverage holes in some areas, or it could partition the network and disrupt data forwarding.

Author evaluate various aspects of the proposed wireless sensor network for forest fire detection and start by assessing the accuracy in estimating the fire indexes FFMC and FWI as a function of the coverage degree k. Then, author evaluate the application of our k-coverage algorithm to the forest fire detection problem.

Author have implemented our own packet-level simulator for the k-coverage algorithm in C++. Simulators like NS- 2 did not scale to the number of nodes (in order of thousands) needed to evaluate our algorithm. Author deploy nodes uniformly at random with the same density over the entire area. We fix an area of size $1km \times 1km$ and vary the coverage degree k between 1 and 8. We set the sensing range of nodes to $100m$. Author employ the energy model in which is based on the Berkeley Mote hardware specifications. In this model, the node power consumption in transmission, reception, idle and sleep modes are 60, 12, 12, and 0.03 mW, respectively. Authors design is based on the Fire Weather Index (FWI) System. Author showed how the forest fire detection problem can be modeled as a k-coverage problem. Author computed the required coverage degrees to achieve a given accuracy level in estimating different components of the FWI System. Author then presented a distributed k-coverage algorithm to solve the k-coverage problem. Authors algorithm is simple to implement and does not require any specific node deployment schemes. Therefore, nodes can be uniformly deployed by, for example, throwing them from an aircraft. This significantly facilitates node deployment in real life. Author also presented a data aggregation scheme based on the FWI System and showed through simulations that our algorithm balances load across all deployed nodes, and therefore maintains reliable coverage and significantly prolongs the network lifetime.

Conclusion: The innovative future directions and to eliminate redundancies. This paper allows a global overview about existing nodes in industrial and research works to get decisions about the future of node fabrication.

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