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A REVIEW PAPER ON WIRELESS SENSOR NETWORK – APPLICATION EARLY WILDFIRE DETECTION

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ABSTRACT

This review paper presents the design of a system for monitoring temperature, humidity and smoke detector for the prevention of Wildfires using wireless sensor networks. An initial study of the causes of Wildfires, like how to prevent them is necessary have a clear idea of how to implement a valid network design that is capable of detecting possible changes in the environment, in that way we can prevent a disaster (Wildfire) that could lead to loss of a significant number of natural resources.

Keywords: Humidity, Sensor Node, Temperature, Wildfire, Wireless Sensor Networks.

I. INTRODUCTION

Research in wireless sensor networks has attracted a lot of attention in recent years. Real applications, such as habitat monitoring, environment and structure monitoring, start to work in practical. In this paper, we argue that wireless sensor network is very promising for fire rescue applications. First, we abstract four requirements of this specific application, including accountability of firefighters, real-time monitoring, intelligent scheduling and resource allocation, and web-enabled service and integration. Based on these requirements and the characteristics of wireless sensor networks, several research challenges in terms of new protocols as well as hardware and software support are examined.

II. WIRELESS SENSOR NETWORK

Sensors integrated into structures, machinery, and the environment, coupled with the efficient delivery of sensed information, could provide tremendous benefits to society. Potential benefits include: fewer catastrophic failures, conservation of natural resources, improved manufacturing productivity, improved emergency response, and enhanced homeland security. However, barriers to the widespread use of sensors in structures and machines remain. Bundles of lead wires and fiber optic “tails” are subject to breakage and connector failures.

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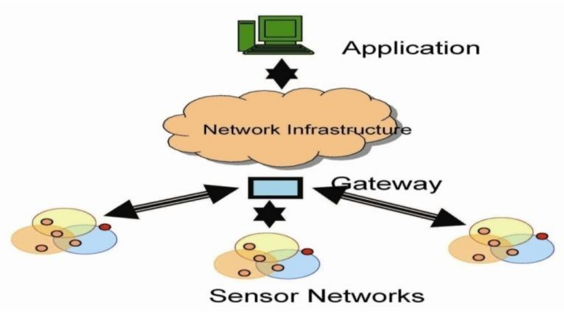

Fig 1. *Basic Structure of Wireless Sensor Network*

Long wire bundles represent a significant installation and long term maintenance cost, limiting the number of sensors that may be deployed, and therefore reducing the overall quality of the data reported. Wireless sensing networks can eliminate these costs, easing installation and eliminating connectors. The ideal wireless sensor is networked and scaleable, consumes very little power, is smart and software programmable, capable of fast data acquisition, reliable and accurate over the long term, costs little to purchase and install, and requires no real maintenance. Selecting the optimum sensors and wireless communications link requires knowledge of the application and problem defi nition. Battery life, sensor update rates, and size are all major design considerations. Examples of low data rate sensors include temperature, humidity, and peak strain captured passively. Recent advances have resulted in the ability to integrate sensors, radio communications, and digital electronics into a single integrated circuit (IC) package. This capability is enabling networks of very low cost sensors that are able to communicate with each other using low power wireless data routing protocols. A wireless sensor network (WSN) generally consists of a base station (or "gateway") that can communicate with a number of wireless sensors via a radio link. Data is collected at the wireless sensor node, compressed, and transmitted to the gateway directly or, if required, uses other wireless sensor nodes to forward data to the gateway. The transmitted data is then presented to the system by the gateway connection.

III. PROTOCOL STACK

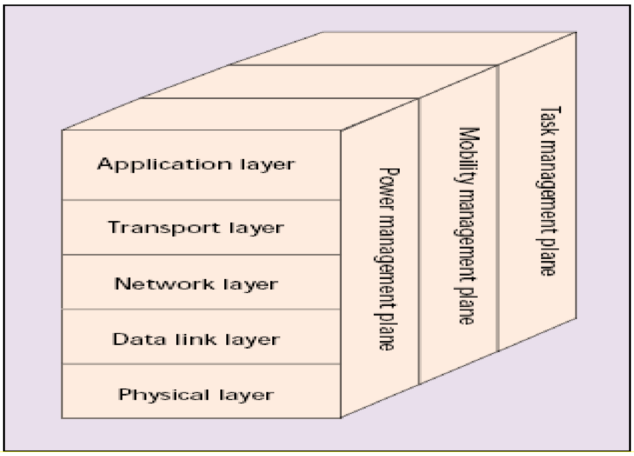

Fig 2. *Wireless Sensor Network Protocol Stack*

IV. MAC PROTOCOLS DESIGN

The design goals of P-CSMA, PHS-CSMA and S-TDMA protocols for Wildfire detection application are the following:

- Energy efficiency
- Data transport reliability
- Simplicity

The energy efficiency is achieved by putting the sensor node in the sleep mode while it is not engaged in the transmission process. However, long sleep time results in longer delay time. Regarding the data transport reliability, alternative paths routing is one of the methods that support better reliability for data delivery [6]. Moreover, alternative paths routing helps the system to survive with some of its nodes being down. To apply the alternative paths method, the intermediate nodes between the source node and the cluster head should have the authority to change the routing path. Using such technique needs every single node to have information about different routes to the sink.

A. Persistent -CSMA

P-CSMA is the simplest MAC protocol among the proposed protocols. Fig. 1 shows the timeline for sensor nodes in P-CSMA. The timeline is composed of wake-up intervals (*Twi*). As shown in the figure, each *Twi* contains active time period *(Tac*) and sleep time period (*Tsl*). During *Tac*, a node turns its transceiver on to receive possible transmissions from other nodes. On the other hand, the node turns its transceivers off during *Tsl* to save power. Basically, no synchronization or coordination does exist between nodes. When a node wants to send a packet, it sends a Request To Send (RTS) message without addressing the receiver node. If there is an awake parent node (i.e. next hop intermediate\ node to the sink), a Clear To Send (CTS) is sent back to the source node after a random back off (BO) time. This BO is necessary to avoid the collisions that could happen in case of more than one parent nodes are awake at that time. Once the CTS is received, the packet transmission will be initiated and all neighbor nodes go to sleep mode. A positive Acknowledgment ACK is used to report a successful transmission. In case of a collision because of a hidden terminal, which was in the sleep mode when the CTS had sent, the whole process will be repeated after a random BO time. If no CTS message was received by the source node (i.e. all parent nodes had been in sleep mode when the RTS was sent), a RTS will be sent again after a fixed BO period time. This fixed BO period should be shorter than *Twi* to make sure that at least one of the parent nodes is able to receive a RTS from the source node. Obviously, in case of one of the source's parent nodes is down, the other parent nodes still can replay to RTS message. This supports alternative routing and data transport reliability as well.

B.Per-Hop Synchronization –CSMA

The second proposed protocol is PHS-CSMA. Fig. 2 shows the timeline for sensor nodes in this protocol. Clearly, the timeline for this protocol is the same as for P-CSMA except that nodes send beacon signals to announce their active mode at the beginning of each *Twi*. Each node should sense the channel before sending its beacon to avoid collisions. The operation of this protocol is as follows: once a node has a packet to send it turns its transceiver on and start listening to the beacons from its neighbor nodes. Based on the routing information, if the received beacon is related to one of parent nodes, it sends a RTS message after a random BO time smaller than *Tac*. This back off is needed to avoid collisions that could happen in case of more than one node are waiting to send for the same node. Now, a CTS message will send back to the source node, and the transmission operation will be initiated. The source's neighbors and those that heard the CTS message from the receiver should go to sleep mode during the transmission. Even if some of these nodes are already waiting for beacons to send their traffic and heard a CTS message, they should go to sleep mode and postpone their waiting process after the current transmission is finished. At the end of the transmission, a positive ACK is required to confirm a successful transmission. Otherwise, the process will be repeated again after a random back off time. A collision between beacons is a very serious problem because such collisions are happen frequently every *Twi*. To solve this problem, a simple algorithm is applied at the earliest phase of this protocol. In this phase, nodes choose their schedule as follows: each node has its own address or ID. Simply, if we have 100 nodes for example, the nodes' IDs will be 1, 2, 3... 100. For each one hope neighbors group, the sensor node which has the smallest ID number chooses its schedule (i.e., when to transmit its beacon during *Twi*) randomly. Other nodes with larger ID wait until hearing all beacons of other nodes that have smaller IDs. For each one of these nodes, the maximum delay time between the received beacons is calculated, and the beacon transmission time is randomly chosen around the middle of that maximum delay time. By doing so, almost uniform distribution of beacons is achieved over *Twi*. As a result, a free beacons collision is achieved.

C. Sensor -TDMA

The third proposed MAC protocol is S-TDMA. This one is the most complex MAC protocol among the proposed protocols because it requires time synchronization between sensor nodes in the same cluster. Many protocols have been proposed for time synchronization. Based on the IEEE 802.15.4 standard, time synchronization can be implemented using a coordinator sensor node. This coordinator broadcasts a beacon signal periodically to allow the other nodes in the cluster to synchronize themselves with the network. In case of multi-hop topology, which is the case in our scenario, more than one coordinator can be used. Timing-sync Protocol for Sensor Networks (TPSN) protocol does not consider such coordinator, and time synchronization is achieved by exchanging synchronization packets between neighbors. A synchronization packet contains timestamps for its source sensor node. Using these time stamps, neighbors calculate the time drift between their clocks. However, time synchronization algorithm is out of the scope of this paper, and sensor nodes are assumed to be time synchronized. According to this protocol, each node in the cluster has its own time slot (outgoing time slot). Using its outgoing time slot, the node sends its messages to its parents. However, a node is not allowed to receive traffic during its outgoing time slot. Therefore, the node goes to the sleep mode in that time slot if it doesn't have traffic to send. On the other hand, each node should be awake in the outgoing time slots that is related to its child nodes (neighbors which it can relay their traffic) to serve their possible traffic. For a certain node, its incoming time slots are outgoing timeslots of its child nodes. Fig. 3 shows the timeline of sensor nodes in this protocol. *Ts* are the time slot while *Twi* is the wake-up interval. During *Twi*, the sensor node will be awake just in its outgoing timeslot and several incoming time slots; otherwise, the sensor node will be in sleep mode to save power. Once a sensor node has traffic, it chooses one of its parents randomly and sends its traffic to the chosen parent during its outgoing timeslot.

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V. THEORATICAL ANALYSIS

It is proposed to implement a WSN system based on using ZigBee, which consist of microcontroller and WSN comprising of different sensors which sense the fire. The system block diagram consists of:

a) Wireless sensor node.

b) Base station.

VI. WIRELESS SENSOR NODE

A wireless sensor network (WSN) is an infrastructure comprised of sensing, computing and communication elements that allows the administrator to monitor & control of the specified parameters in the network. Typical application of WSN includes data collection, monitoring, surveillance.

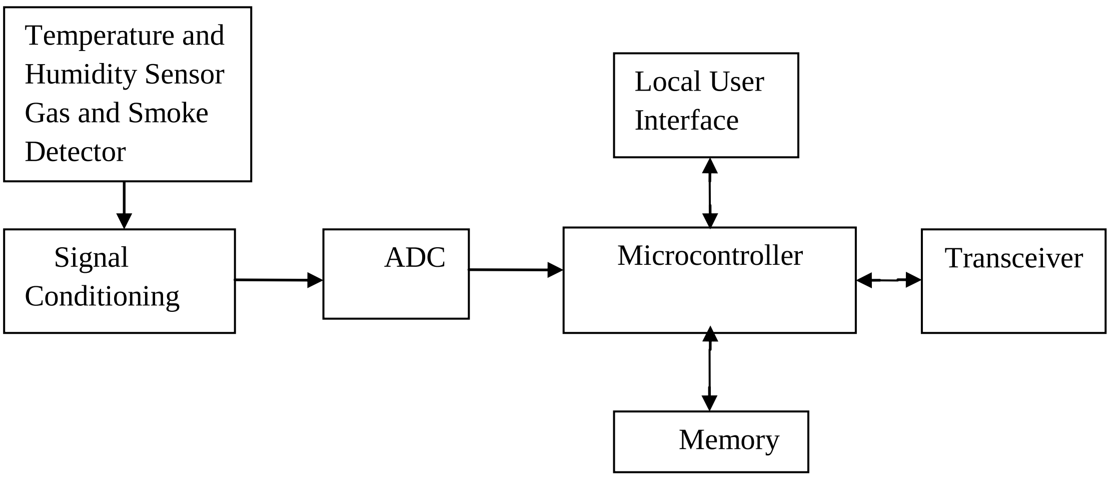

Fig.3 *Components of a Sensor node*

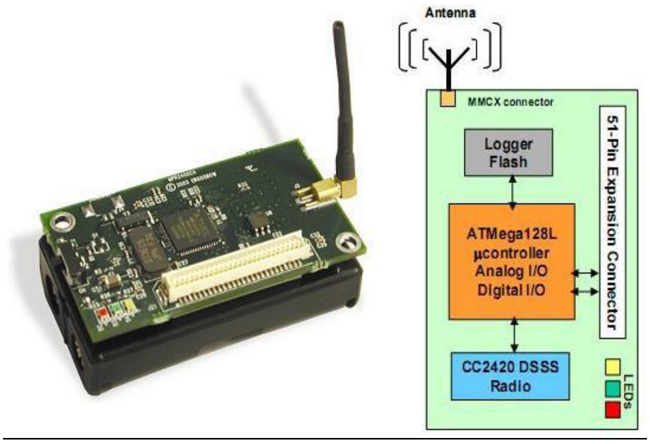

Fig 4. *Sensor Node*

VII. FIRE CHARACTERISTICS

There are three phases for fire formation

Phase I: Gas sensor for sensing Invisible Gases

Carbon monoxide (CO), Carbon Dioxide CO_2), Molecular Oxygen (O_2), Methane (CH_4), Molecular Hydrogen (H_2), Ammonia (NH_3), Isobutene (C_4H_{10}), Ethanol (CH_3CH_2OH),

Toluene ($C_6H_5CH_3$), Hydrogen Sulphide (H_2S)

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Nitrogen Dioxide (NO_2)

Phase II: Optical sensor for sensing smoke and large particals.

Phase III: Fire and Temperature sensor

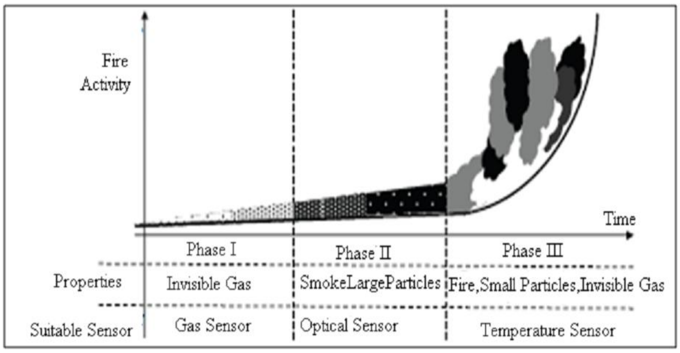

Fig.5 *Fire Characteristics diagram*

TEMPERATURE AND HUMIDITY SENSOR

Sensirion's family of relative humidity and temperature sensors have become established as the industry standard - mainly due to their high performance and integration (CMOSens Technology) in a miniature format. The capacitive humidity and temperature sensors provide digital and fully calibrated output which allows for easy integration without the need for additional calibration. The excellent long term stability has been very well perceived and the cutting edge low energy consumption is unachieved and makes them the right choice for any remote application.

Humidity and Temperature Sensor		Packaging	Max. RH tolerance	Max. T tolerance
SHT10		SMD	±4.5%RH	±0.5°C
SHT11		SMD	±3%RH	±0.4°C
SHT15		SMD	±2%RH	±0.3°C
SHT21		DFN	±3%RH	±0.4°C
SHT25		DFN	±2%RH	±0.3°C
SHT71		Pins	±3%RH	±0.4°C
SHT75		Pins	±1.8%RH	±0.3°C
STS21		DFN	-	±0.3°C

Table 1: *Humidity and Temperature sensors*

The humidity sensors are provided in different packaging types: SMD type (SHT1x series), pin type (SHT7x series) and the new DFN type (SHT2x series). The SHT1x and SHT2x are reflow solderable while pin type humidity sensors are used for devices where flexible integration is crucial or easy exchange is necessary.(SHT10, SHT11 ,SHT15, SHT21, SHT25, SHT71, SHT75, STS21)

VIII. OPTICAL SMOKE DETECTOR

A smoke detector is a device that detects smoke, typically as an indicator of fire. An optical detector is a light sensor. When used as a smoke detector, it includes a light source (incandescent bulb or infrared LED), a lens to collimate the light into a beam, and a photodiode or other photoelectric sensor at an angle to the beam as a light

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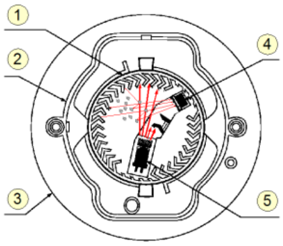
detector. In the absence of smoke, the light passes in front of the detector in a straight line. When smoke enters the optical chamber across the path of the light beam, some light is scattered by the smoke particles, directing it at the sensor. Kidde 900-0102 Combination Smoke and Carbon Monoxide Detector (MPN: 9000102)



1. Optical Chamber
2. Cover
3. Case Moulding
4. Photodiode
5. Infra red LED

Fig 6. *Smoke detector*

IX. MICROCONTROLLER UNIT

Microcontroller like ARM (LPC 2148) performs tasks, processes data and control the functionality with other components in the sensor node. This also sends the data to the RF transceivers for the transmission of data to the base station. The microprocessor has a number of functions including:

1. Managing data collection from the sensors
2. Performing power management functions

Interfacing the sensor data to the physical radio layer

Managing the radio network protocol.

The LPC2141/2/4/6/8 microcontrollers are based on a 32/16 bit ARM7TDMI-S CPU with real-time emulation and embedded trace support, that combines the microcontroller with embedded high speed flash memory ranging from 32 kB to 512 kB. A 128-bit wide memory interface and unique accelerator architecture enable 32-bit code execution at the maximum clock rate. For critical code size applications, the alternative 16-bit Thumb mode reduces code by more than 30 % with minimal performance penalty. Due to their tiny size and low power consumption, LPC2141/2/4/6/8 are ideal for applications where miniaturization is a key requirement, such as access control and point-of-sale. A blend of serial communications interfaces ranging from a USB 2.0 Full Speed device, multiple UARTS, SPI, SSP to I2Cs and on-chip SRAM of 8 kB up to 40 kB, make these devices very well suited for communication gateways and protocol converters, soft modems, voice recognition and low end imaging, providing both large buffer size and high processing power. Various 32-bit timers, single or dual 10-bit ADC(s), 10-bit DAC, PWM channels and 45 fast GPIO lines with up to nine edge or level sensitive external interrupt pins make these microcontrollers particularly suitable for industrial control and medical systems.

Device	Pins	On-Chip RAM	USB RAM	ON-Chip Flash	ADC Channels	DAC Channels
LPC2141	64	8 kB	2 kB	32 kB	6	-
LPC2142	64	16 kB	2 kB	64 kB	6	1
LPC2144	64	16 kB	2 kB	128 kB	14	1
LPC2146	64	32 kB	2 kB	256 kB	14	1
LPC2148	64	32 kB	2 kB	512kB	14	1

Table 2: *ARM devices*

X. RF TRANSCEIVERS

In the proposed system the RF transceivers like CC 2420 can be used together with a microcontroller and a few external passive components. This transmits & receives data from Sink Node or base station to wireless node & vice versa. Zig-Bee is a Technological Standard Created for Control and Sensor Networks based on the IEEE 802.15.4 specification for wireless personal area network .It is a new wireless technology that has application in various fields. Zig-Bee benefits are low cost and Range and obstruction issues avoidance. The main features of this standard are network flexibility, low cost, very low power consumption, and low data rate in an ad-hoc self-organizing network among inexpensive fixed, portable and moving devices.

Model	Protocol	Frequency	TX power	Range
XBee-802.15.4	802.15.4	2.4 GHz	1 mW	500 m
XBee-802.15.4-Pro	802.15.4	2.4 GHz	63 mW	7000 m
XBee-ZigBee	Zigbee-Pro	2.4 GHz	2 mW	500 m
XBee-ZigBee-Pro	Zigbee-Pro	2.4 GHz	50 mW	7000 m
XBee-868	RF	868 MHz	315 mW	40 km
XBee-900	RF	900 MHz	50 mW	10 km
XBee-XSC	RF	900 MHz	100 mW	24 km

Table 3: *Comparison of different Zig-bee Models*

ROUTING PROTOCOL

Due to differences in wireless sensor network and ad-hoc network, many new algorithms have been proposed for the routing problem in WSNs. These routing mechanisms have taken into consideration the inherent features of WSNs along with the application and architecture requirements. The task of finding and maintaining routes in WSNs is nontrivial since energy restrictions and sudden changes in node status (e.g., failure) cause frequent and unpredictable topological changes. To minimize energy consumption, routing techniques proposed in the literature for WSNs employ some well-known routing tactics as well as tactics special to WSNs, such as data aggregation and in-network processing, clustering, different node role assignment, and data-centric methods. Almost all of the routing protocols can be classified according to the network structure as: Flat Routing, Hierarchical Routing and Location - based Routing. Furthermore, these protocols can be classified into different class depending on the protocol operation as: Multipath-based, Query-based, Negotiation-based, Quality of service (QoS)- based and Coherent-based. In flat networks all nodes play the same role, while hierarchical protocols aim to cluster the nodes so that cluster heads can do some aggregation and reduction of data in order to save energy. Location-based protocols utilize position information to relay the data to the desired regions rather than the whole network. The last category includes routing approaches based on protocol operation, which vary according to the approach used in the protocol.

In addition to the above, routing protocols can be classified into three categories, proactive, reactive, and hybrid, depending on how the source finds a route to the destination. In proactive protocols, all routes are computed before they are really needed, while in reactive protocols, routes are computed on demand.

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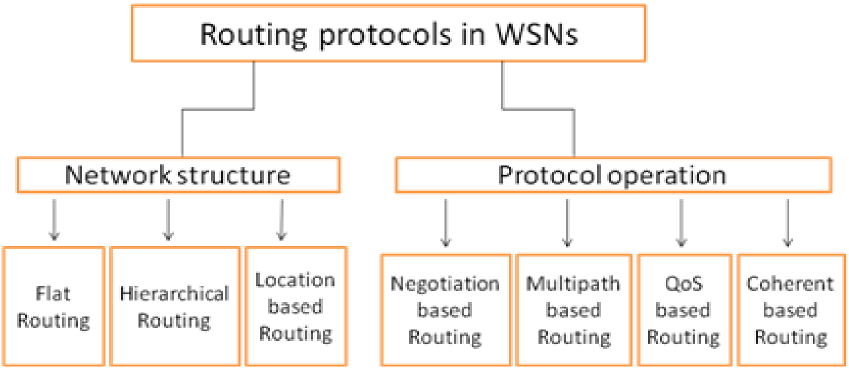

Fig.7. *Different Protocols*

In addition to the above, routing protocols can be classified into three categories, proactive, reactive, and hybrid, depending on how the source finds a route to the destination. In proactive protocols, all routes are computed before they are really needed, while in reactive protocols, routes are computed on demand. Hybrid protocols use a combination of these two ideas. When sensor nodes are static, it is preferable to have table-driven routing protocols rather than reactive protocols. A significant amount of energy is used in route discovery and setup of reactive protocols. Another class of routing protocols is called *cooperative*. In cooperative routing, nodes send data to a central node where data can be aggregated and may be subject to further processing, hence reducing route cost in terms of energy use. Many other protocols rely on timing and position information.In the wildfires sensor network, the routing protocol uses similar to other flat routing protocol using Minimum Cost path Forwarding (MCF) [2]. MCF finds shortest paths from all the sensor nodes to the base station and requires no explicit routing tables to maintain each node. Routing all the data along a shortest path might potentially drain all the energy from upstream nodes. Thus, there might be lost-coverage regions of the network. MCF design has been driven by the following three goals: Optimality, Simplicity and Scalability. Sensor node starts when its power on. It has random timer and processes periodically.

XI. CONCLUSION

Wildfires have multidimensional negative effects in social, economic and ecological matters. Unfortunately, Turkey is one of the countries subjected to wildfires every year. It is difficult to say that fire fighting can be successful without enough data about fire such as spread direction and speed etc. The more data about wildfire means the more effective fire management. Economically, fire fighting is well known to be a costly task. It is wise to invest in early warning systems which are definitely much less costly on the whole. WSNs are thus the right choice and the least costly of all surveillance and early detection systems. The ongoing research in wireless sensor networks is promising that cost effective systems shall immerge for Wildfire sensing and detection applications. Finally, we conclude that wireless sensor network is a very powerful and suitable tool to be applied in this application.

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