Environmrnal Monitoring in Flammable Climate Zones over IoT Cloud

Lela Mirtskhulava [1], Lele Tvaliashvili [1], Avtandil Bardavelidze [2], Luka Tvaliashvili [1]

[1] *Department of Computer Science*, Iv. Javakhishvili Tbilisi State University/San Diego State University Georgia.
[2] *Information Technology Department*, Faculty of Exact and Natural Sciences, Akaki Tsereteli State University, Kutaisi, Georgia.

lela.mirtskhulava@tsu.ge; tvaliashvililela@gmail.com; avtandilbardavelidze@atsu.edu.ge; lukatvaliashvili@gmail.com

***Abstract* - An effective framework is proposed for Intelligent Environmental monitoring in dry and flammable zones using wireless sensor networks for real-time fire detection. The wireless sensor network can give more accurate detection of fire danger rate over Internet of Things (IoT). Two models were designed: i) a first given model, WSN consists of various sensors forming the sensor nodes, which measure the basic environmental parameters like temperature, humidity and the level of flammable gases in the given environment. We used Arduino as a microcontroller board capable to transmit data via Bluetooth module to the smartphone. Android smartphone application is capable to display temperature data. ii) in the 2nd model, we simulated IoT environment monitoring using Cisco Packet Tracer. In this model IoT environment was built to automatically detect fire by using remote fire sensor. MCU board simulates Arduino which is connected to temperature and smoke sensors and acting like the remote fire detection unit. MCU was connected to home gateway and secured. Fire alarm system was connected to a home gateway where a SBC board was connected to an alarm actuator. Both systems were connected and registered to IoE server to provide automated process to raise the alarm when fire is detected by the fire sensor.**

Keywords – IoT, fire monitoring, Arduino, WSN, climate zones

I. INTRODUCTION

I'll start with the Long and Fox citation: "…the earth enables our people to survive, the environment must be respected and maintained. As long as the earth remains healthy, the people remain healthy." (Long and Fox, 1996).

Global warming scale cause irreversible processes and most of globe population unable to recognise urgency of these issues what needs to be addressed. Climate change have been caused by plenty of reasons including quite different infrastructures. Global warming is stoppable what could be achieved improving transport infrastructure to reduce congestion, reducing the power consumption of smartphones and all kind of electronic equipment what can benefit economically and even reduce carbon footprint." Climate change has affected our ecosystems. So, our ecosystem requires paying an attention to [1].

Ecosystem is an area of living organisms (biotic) and non-living (abiotic) components like a pond or a house as well as our Earth is our ecosystem. Abiotic components are an air, water, sunlight, Nutrients and temperature. Biotic or living organisms implies plants, animals, fungi, micro-organisms and humans along with abiotic components like soil, nutrients, air and etc. Every component or organism living in an ecosystem has its own role. Humans are ecosystems of thousands of micro-organisms that inhabit in human organisms. Our ecosystem is very important. First we need stop polluting our ecosystem, otherwise Earth no more would be a habitable ecosystem.

Massive wildfires, in our country Georgia, destroyed an area of 250 hectares of Borjomi National Park in 2008 and 750 hectares in August 2017 totally where the an ecological function of an ecosystem of the forest has been lost (fig.1.). The fire started on Sunday in Borjomi- Kharagauli National Park of Georgia but intensified on Monday evening when it spread to over 6 hectares in the hills above the villages Tsaghveri, Sadgeri and Daba. It is about five kms south-east of the town Borjomi, a popular mountain resort.

Fig. 1. Wildfire

Borjomi-Kharagauli National Park is one of the largest national parks in Europe, located in central part of Georgia and creates eastern part of lesser Caucasus Mountains. Borjomi was famous with mineral water spa and green nature of Georgia. Borjomi-Kharagauli National Park is the first National Park in the Caucasus region satisfying international standards. It was created in 1995 supported by

WWF and German government for preserving the region's extraordinary nature. The Park was characterised with several natural zones thanks to variety of trees from broad-leafed groves to evergreen and sub-alpine trees in its ascent from 800 to 2700 meters [2].

California is well-known for wildfires gradually destroying California forest ecosystem. But The Camp Fire in November 8, 2018 destroyed about 18 000 structures in Paradise what was most destructive wildfire in the history of California [3]. I'm witness of this horrible accident where air quality was considered hazardous even in San Jose where I lived in 2018- 2019 academic year enjoying my Fulbright visiting scholarship program. The health department urged people to stay inside or use N95 respirators and P100 masks for those who has to go outside. Due to unhealthy air in Stanford and Berkeley football match was postponed until December 1, 2018.

Ecological problems can be translated into decision optimization and statistical problems like combinatorial decisions, dynamic modeling, and uncertainty but on the other side, environmental monitoring applications are using the sensors to detect and prevent fire, to monitor air quality, water, and soil. Intelligent environmental monitoring and management systems are associated with the concept of IoT through the use of sensors and networked embedded devices where interconnected devices enable to transmit the measurement information and the instructions via wireless sensor networks.

II. INTERNET OF THINGS

In 1990, John Romkey, one of the developers of the TCP / IP protocol, connected his toaster to the Internet and made it turn on and off remotely. This device became the first "Internet thing" in the world. Between 2008 and 2009, according to Cisco analysts, the number of devices connected to the World Wide Web exceeded the world's population.

Internet consists of plenty of the computer networks where they differ by their mission and classified as scientific, government home and corporate computer networks. Networks differ on topologies and architectures combined through the IP protocol. Each node in a Network is assigned a permanent or temporary IP address [3-10].

Internet of things today consists of many loosely interconnected networks, each of which solves its own problems. For example, in one office building several networks can be deployed altogether for controlling air conditioners, heating system, lighting, security, etc. These networks can work according to different standards, and combining them into one network what is a non-trivial task.

In addition, the existing standard like fourth version of the IP protocol (IPv4) allows the users to use only 4.22 billion addresses and that's why there is a problem of their exhaustion. Not every device connected to the Network needs a unique IP address (but still needs a unique identifier), due to the rapid growth of the Internet of things, the problem of address shortages can become a limiting factor. The sixth version of the protocol, IPv6, will help to solve it radically, which will provide the opportunity for every inhabitant of the Earth to use more than 300 million IP addresses [11-15].

Intelligent Environmental monitoring can be achieved using sensors through the physical infrastructure consisting of information and communication (ICT) technologies. The major vision of intelligent systems is associated with the concept of IoT. The objects falling into the scope of Internet of Things consists of embedded networked devices like thermostats, electronic appliances, connected security systems, cars, alarm clocks and lights in commercial and household environments capable to transmit vital measurement information through the distributed wireless sensor networks. We can differentiate four main IoT phases like network infrastructure, cloud technologies, wireless sensor networks, real world interface (smartphones) (table I).

TABLE I. IOT PHASES.

IoT Phases
Phase 1: Network Infrastructure
Network Transmission and Topology
Widen network coverage
Increase the network addresses
Strengthen the network connectivity
Increase the network capacity
Phase 2: Cloud Technologies
Increase the data capacity storage
Increase the database availability
Phase 3: Wireless Sensor Network
• IP-based network
• Integrate and find possible IP based sensors
Phase 4: Real World Interface
Accessibility
User Friendly
Integrate through smart phones
Improve Security
Increase energy efficiency and use clean energy

III. WIRELESS SENSOR NETWORS

Wireless sensor networks (WSN - fig.1) are the wireless networks including spatially distributed devices, called sensors, monitoring physical or environmental conditions. WSN applications provide accurate, reliable and real-time information enabling area monitoring, Health care monitoring, Environmental/Earth sensing, air pollution monitoring, forest fire detection, landslide detection, water quality monitoring, natural disaster prevention, Data center monitoring, health monitoring and etc.

WSNs were invented as small wireless sensors using for collecting information from different physical environments including industrial monitoring, agriculture management, wildfire tracking and animal observation. The sensors can transmit an information over electromagnetic waves toward a base station helping each other in this process (fig.2.). Research field of WSNs gained popularity since the early 2000s.

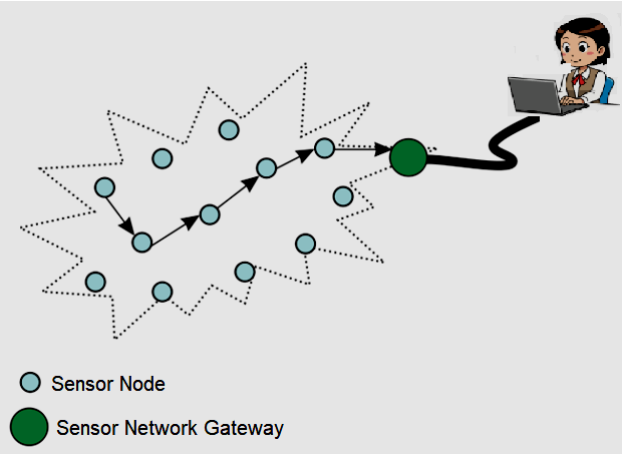

Fig. 2. Schematic View of Wireless Sensor Networks

Wireless Sensor Network can be implemented in a forest capable to detect a fire immediately. The nodes are equipped with the sensors capable to measure temperature and gases which are produced by fire in a forest (fig.3.). Early fire detection is vital for firefighters to extinguish the fire where wireless sensor networks come in.

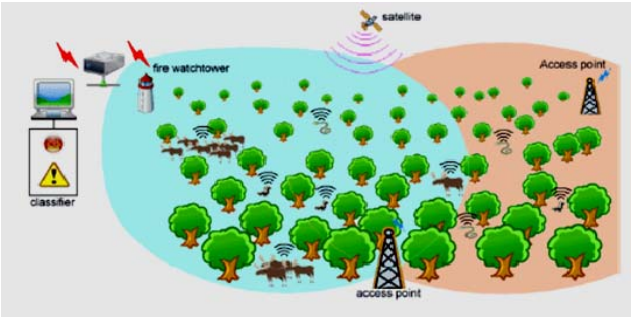

Fig. 3. Smart Forest.

IV. PROPOSED FRAMEWORK

An effective framework is proposed using wireless sensor network for real-time fire detection. The wireless sensor network can give more accurate detection of fire danger rate over IoT.

In the given framework, we propose to use WSN model consisting of various sensors forming the sensor nodes, which measure the basic environmental parameters like temperature, humidity and the level of flammable gases in the given environment. We're using Arduino as microcontroller board capable to transmit data via Bluetooth module to the smartphone. Android smartphone application is capable to display temperature data.

A. Arduino

Arduino is inexpensive and small-sized single-board computer. It is cross-platform running on Windows, Mac OS X, and Linux and easy in programming. Hardware and software of Arduino are open source and extensible (fig.4).

Arduino is powerful computing platform along with the original navigation computers. It is used worldwide by programmers and designers taking an advantage of the power of Arduino and its simplicity in creating sorts of innovative devices such as interactive sensors, toys and artwork.

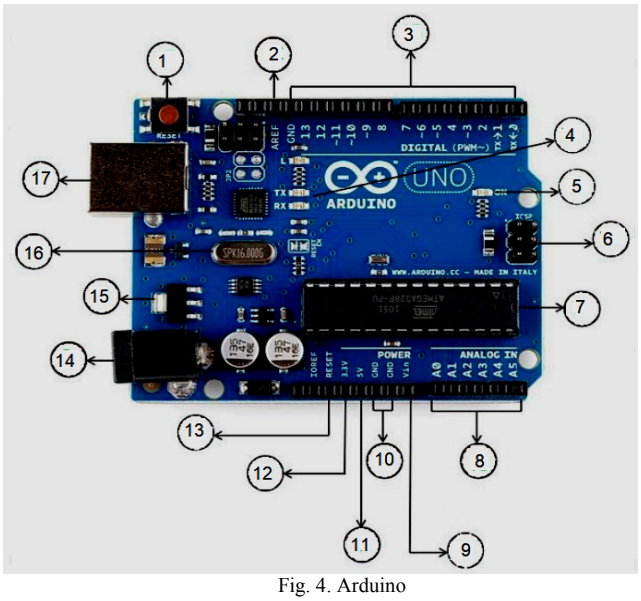

Fig. 4. Arduino

1. **Reset button:** reset the board
2. **AREF pins:** set an external voltage for the analog pins as the upper limit
3. **Digital I/O pins:** 14 pins capable of reading and outputting digital signals; 6 of these of these pins are also capable of PWM
4. **RX and TX LEDs:** receive (RX) and transmit(TX) LEDs, blink when sending or receiving serial data respectively
5. **Power indicator LED:** indicates the board power status
6. **ICSP pin:** a programming header on the board also called SPI
7. **Microcontroller(ATMega328):** the processing and logical unit of the board
8. **GND pin:** to ground the circuit
9. **Vin pin:** to supply power to the board
10. **Analog pins(A0-A5):** to read analog signals to the board

11. **5V pin:** a 5V output
12. **3.3V pin:** a 3.3V output
13. **Reset Pin:** to reset the Arduino Uno
14. **Barrel Jack:** for power supply
15. **Voltage Regulator:** regulates and stabilises the input and output voltages
16. **Crystal Oscillator:** keeps track of time and regulates processor frequency
17. **USB:** used for both power and communication with the IDE

B. System Overview

A Sensor is a small-sized device capable to measure a physical quantity and then convert it into a signal transmitted through electronic instrument.

An Actuator is a motor type designed for moving a systems or some mechanism operated by power source like electric current, pneumatic pressure or hydraulic fluid pressure and converting the energy into motion. An actuator is main mechanism in Arduino through which a control system can act on an environment.

Integrated Development Environment (IDE) of Arduino consists of a text editor for coding, a text console, a message area and a toolbar with common functions and a menu bar. IDE gets connected to Arduino hardware board uploading codes and then communicating to with them.

C. Fire Detection Using Arduino and Flame Sensor

Our model consists of a flame sensor interfaced Arduino detecting flame. Led and buzzer interfaced to Arduino indicating flame as well (Fig. 5).

Hardware components:
1. Arduino
2. Flame sensor
3. Breadboard
4. LED
5. Buzzer
6. Connecting wires

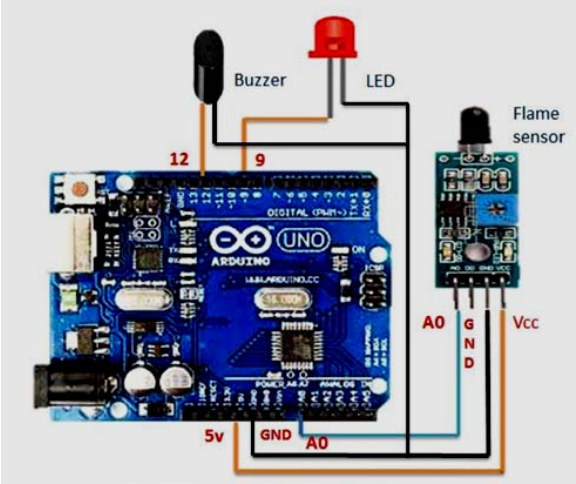

Fig. 5. Flame Detection using Arduino

Hardware connections:
- Flame sensor interfacing to Arduino
- VCC - > VCC
- GND - > GND
- A0 - > A0

Led interfacing to Arduino:
- LED +ve is connected to 9th pin of Arduino
- LED -ve is connected to gnd pin of arduino
- Buzzer interfacing to Arduino
- Buzzer +ve is connected to 12th pin of Arduino
- Buzzer -ve is connected to GND pin of Arduino

LED and Buzzer getting ON automatically when flame occurs and they getting OFF automatically when no flame take place. Here based on a room condition the threshold value taken was 100 for the Flame sensor. When placing a flame near flame sensor Arduino automatically turns on the LED and Buzzer. When removing a Flame from flame sensor Arduino automatically turns Off LED and buzzer. Fig. 5.

Integrated Development Environment (IDE) of Arduino or Arduino Software allows to write a code using a text editor, a text console, a message area, a toolbar and the buttons having common functions and different menus. It allows to be connected to the Arduino board to upload the programs and make communication with them.

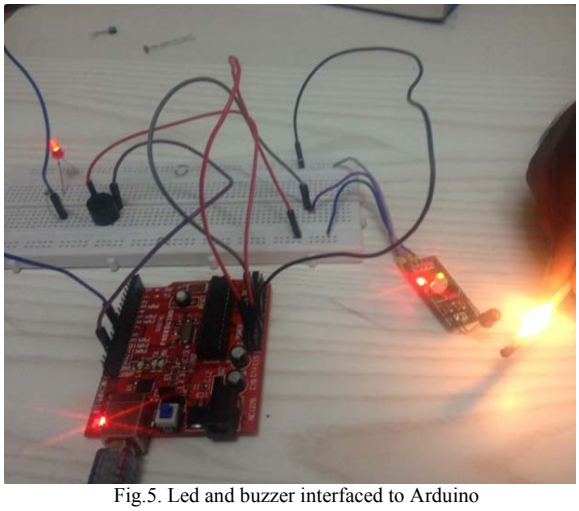

Fig.5. Led and buzzer interfaced to Arduino

V. FIRE DETECTION SIMULATION IN CISCO PACKET TRACER

Packet Tracer is a visual simulator developed by Cisco Systems allowing to create various network topologies, configure Cisco devices can be configured via command line interface (CLI) like real switches and routers. Latest version of packet tracer contains various smart things divided into different categories like smart home, smart city, power grid and industrial. All these things can be connected to the home gateway, registration server and MCU-PT (microcontroller) and SBC-PT (single boarded computers).

Mainly, three types of components like boards, actuators and sensors gives us an opportunity to prototype environmental monitoring. Boards like MCU-PT, SBC-PT and thing (special device) can act as the self-contained physical objects like smoke alarms. Actuators can manipulate the environment and the area. Sensors can sense an environment (temperature sensor) and the area and etc. MQTT (Message Queuing Telemetry Transport) protocol is ISO standard protocol capable to transfer the packets between IoT devices running over TCP/IP (Transmission Control Protocol/Internet Protocol).

We are simulating an environment monitoring using IoT capabilities in Cisco Packet Tracer. In this model IoT environment was built automatically detecting fire by using remote fire sensor. MCU board simulates Arduino connecting temperature and smoke sensors and acting like the remote fire detection unit. MCU is connected to home gateway and secured. Fire alarm system is connected a home-gateway consisting of a SBC board connected to an alarm. Both systems are connected and registered to IoE server providing automated process raising a fire alarm when fire is occurred and detected by using the fire sensor.

Home Gateway supports 4 Ethernet ports and a wireless access point with default SSID "Home-Gateway" on channel 6. WPA2 protocol is used for securing wireless communication. Ceiling Sprinkler affects Humidity at a rate of 5% per hour. Temperature Sensor detects Ambient Temperature. Smoke Sensor detects smoke

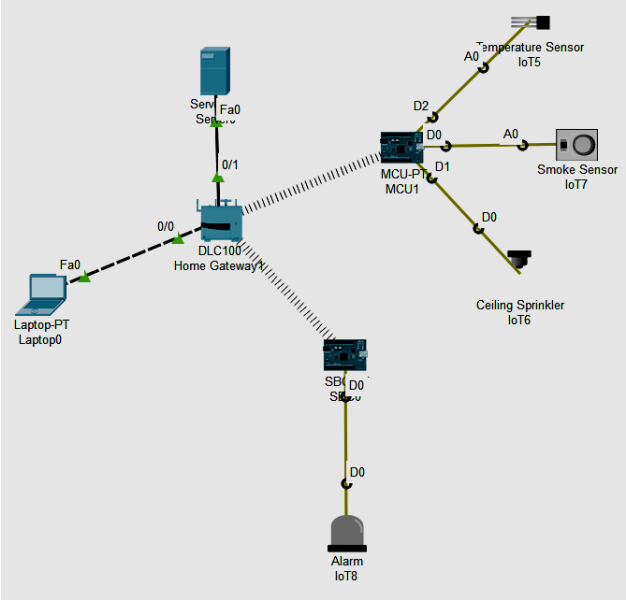

Fig. 6. Fire monitoring in Cisco Packet Tracer

Home gateway web interface includes IoE programming editor that allows Python programming of MCU microcontroller. Code runs through the web interface and then through MCU board.

VI. CONCLUSIONS AND FUTURE WORK

We prototyped IoT environmental monitoring system using wireless sensor network enabling accurately detect fire in real-time mode and measure fire danger rate over IoT. We proposed the WSN model consisting of various sensors forming the sensor nodes, which measure the basic environmental parameters like temperature, humidity and the level of flammable gases in the given environment. Main component in this model was an Arduino that acted as a microcontroller board capable to transmit data via Bluetooth module to the smartphone. Android smartphone application has been developed for displaying temperature data allowing us to securely transmit this data remotely over Wi-Fi networks.

We simulated an environment monitoring in Cisco Packet Tracer using IoT capabilities. In this IoT environment, a remote fire sensor has been used to automatically detect a fire. MCU board simulates Arduino which can connect temperature and smoke sensors acting as the remote fire detection unit. MCU has been registered to home gateway and secured. Fire alarm system has been registered to a home-gateway through a SBC board which is connected to an alarm enabling to automatically raise a fire

alarm if fire has been occurred and detected by using the fire sensor.

Future Work: Recently we got a good news from EU commission. Our project named "International Interdisciplinary Network on Smart Healthy Age-friendly Environments" was finally approved and published where I'm invited as the secondary proposer. The main objective of the given project is to develop an international ecosystem based on a network of scientists that enables the deployment of Smart Healthy Age-Friendly Environments (SHAFE). The primary purpose is to reach every single COST country and Georgia among them for spreading awareness and developing the SHAFE concept in rural and urban areas. What gives me a huge opportunity to extend my research activities in Smart Environmental Monitoring. You can find an information about this project through this website.

REFERENCES

[1] Environment, health, life expectancy and social inequalities are linkedhttps://www.eea.europa.eu/soer/synthesis/synthesis/chapter5.xhtml. 2016

[2] 2008 Borjomi Wildfire: https://en.wikipedia.org/wiki/2008_Borjomi_Wildfire

[3] Camp Fire (2018). https://en.wikipedia.org/wiki/Camp_Fire_(2018)

[4] 2."Internet of Things Global Standards Initiative". ITU. Retrieved 26 June 2015.

[5] 2. Rouse M. "internet of things (IoT)". IOT Agenda. August 2019.

[6] 3. Ashton, K. (22 June 2009). "That 'Internet of Things' Thing". 2017.

[7] 4. Magrassi, P; Berg, T. "A World of Smart Objects". Gartner research report R-17-2243. 2002

[8] 5. Commission of the European Communities (18 June 2009). "Internet of Things – An action plan for Europe" (PDF). COM(2009) 278 final.

[9] 6. Vongsingthong, S.; Smanchat, S. (2014). "Internet of Things: A review of applications & technologies" (PDF). Suranaree Journal of Science and Technology.

[10] 7. Greengard, Samuel. The Internet of Things. Cambridge, MA: MIT Press. p. 90. ISBN 9780262527736. 2015

[11] 8. Tan, Lu; Wang, Neng. Future Internet: The Internet of Things. 3rd International Conference on Advanced Computer Theory and Engineering (ICACTE). 5. pp. 376–380.

[12] doi:10.1109/ICACTE.2010.5579543. ISBN 978-1-4244-6539-2. 2012

[13] 9. Hui, J., Culler, D.: IP is Dead, Long Live IP for Wireless Sensor Networks. Proc. 6th Int. Conf. on Embedded Networked Sensor Systems (SenSys), pp. 15–28. 2008

[14] 10. Brown, Ian. "Regulation and the Internet of Things" (PDF). Oxford Internet Institute. 2016

[15] 11. McEwan, Adrian (2014). "Designing the Internet of Things" (PDF). 2016.