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Low-cost smart-home for rural areas of Pakistan

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Abstract

A number of issues and challenges are associated with the lives of people living in the rural areas of Pakistan due to natural disasters and other hazards. Wireless sensor networks are being used in a number of applications that can provide timely relief in hazardous or disastrous conditions. In this paper a wireless sensor network based low-cost smart-home network has been proposed to provide comfort and timely relief to the residents of rural areas under consideration. A prototype has been designed and implemented in two phases; simulation and hardware implementation. The simulation outlines the possible challenges that may be faced during the hardware implementation. The hardware implementation phase involves actual sensing and processing using hardware devices. The proposed prototype is tested and evaluated in real time.

Keywords: *WSN, Smart-home, Low-cost*

I. INTRODUCTION

Recently, there has been an increase in the popularity of home-automation or smart device connectivity, which may include communication and utilities. A smart home is thought to possess some intelligence that may assist its inhabitants in various ways and to improve the quality of life [1]–[3]. The overall goal of smart-home is to bring comfort to its populations while reducing the overhead on the budget (with respect to utilities). A wide variety of smart home services may be created depending on the type of devices and communication respectively [4].

While utilities may span from smart meter reading, smart sensing networks, home-security network to automated devices and their connectivity using short-range technologies, the communication among those devices and its challenges play a vital role in establishing a smart home. However, there is a need for consumer awareness with respect to how to control home expenditure with the help of using new technologies and responsible energy consumption by every household in a community

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[5], [6]. Sriskanthan et al., in [10] have presented automated system that is based on Bluetooth wireless technology to provide monitoring and control for various appliances. These appliances are connected with the central system via Bluetooth which can be controlled using a mobile cell. Maqsood, J., on the other hand in [11] has discusses and implemented a number of techniques to design a home automation system. This system also uses Bluetooth technology and has an Android App has also been designed to provide system services control. The App provides in-door and outdoor management of the devices via Bluetooth and GSM technologies. Arduino has been used to integrate the system. Nevertheless, Cubukcu, A. et al., have designed a remote control in [12] that makes use of speech recognition control home devices. Moreover, Adriansyah, A. et al., in [13] presented a prototype monitor and control alarms, lights, home appliances, room temperature, alarms, etc., in a home. Globally, a number of solutions have been suggested to provide comfort and ease of device usage at home and away. However, the smart home concept does not only deal with remote usage of home appliances or other device, it can also be used to monitor and provide timely relief in different critical situations. There can be enormous applications that may be used to not only to help people do everyday chores but to actually help save lives and to stay in touch with the loved ones at home.

With increasing population of Pakistan, while rural residents make up a two-third of the country's total population, the number of health issues in remote/rural areas of Pakistan are increasing day by day. Nevertheless, there has been a considerable increase in the natural disasters in Pakistan over the decade [7]. These disasters may range from heavy rainfall leading to severe floods to deadly earthquakes. Due to limited resources available to people living in the rural areas of the four provinces, warnings and timely relief cannot be provided.

A large number of rural areas in Pakistan are deprived of basic home necessities such as water supply, gas connection, electricity and road links. In many parts of Pakistan, during winter, use of solid fuels is common. These provide a cost-effective solution to warming home in winter, cooking, etc., in rural areas particularly where gas connections are not available. Nevertheless, people in such areas also rely on gas cylinders. A number of deaths have been associated with gas leaks and carbon monoxide (CO) poisoning in Pakistan every year [8]. Hence, such issues, other than natural disasters, also need attention and timely measures to save precious lives. A possible and attractive solution to consider is wireless sensor networks (WSNs). WSN applications may be deployed in a wide variety of environments and can be used for monitoring and tracking [9]. Smart homes may contain multiple applications/devices connected or communicating for the purpose of health monitoring, home environment monitoring, entertainment, security system, etc. Providing a low-cost smart-home solution to rural areas may uplift the health and quality of life of people.

In this paper both categories have been focused in order to provide a low-cost smart-home solution for rural areas of Pakistan. Rest of the paper has been organized

as follows. Section II discusses the requirement analysis and the design of the prototype. Simulation details have been discussed in section III. Hardware implementation, with detailed description of the devices and the outcome, has been presented in section IV. Section V presents conclusion and future work.

II. PROTOTYPE DESIGN

A number of issues are related to lives of people living in the rural area of Pakistan. With the help of latest technologies, an effort may be taken to improve the living and health conditions. The issues and challenges faced by people living in specific rural area may depend upon:

- Geographical location and effects of environment on that region
- Living condition of the residents
- Vulnerability and monitoring with respect to health and environment

Designing a smart home may involve choosing specific devices, sensors, connectors, etc. However, all together it is quite challenging to choose a suitable network to provide low-cost smart-home services. The challenges to consider may include:

- Type of monitoring and its severity
- Back bone network
- Implementation cost
- Deployment strategies, etc.

In this section, the design concept of the proposed prototype is discussed in detail which mainly focuses on development of low-cost smart home scenario especially for people living in rural areas of Pakistan.

A. Concept

The design mainly focuses the small houses/huts situated in the remote areas of Pakistan. The only considered assumption is that the cellular communication is possible in such areas (i.e., GSM Signals). The prototype is designed to help achieve the goal of saving vital lives of people unable to afford pricy monitoring devices and timely management of severe situations. The perception of a smart home in this scenario is mainly related to designing a prototype of a system capable of providing information regarding various phenomenon related to different situations in a home to provide timely relief in case of a mishap. This design includes detection and monitoring, processing and communication of the phenomenon.

Rural areas of Pakistan are sparsely populated especially Northern region of Pakistan where houses are built on mountains or in valleys. The communication among these homes is poor as the residents neither meet their neighbor everyday nor

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do they visit the nearby markets often, as these nearby markets are located several miles from where these people reside. In such scenario, cellular network may be the only option available that can be used to send timely alerts to the nearby relief services. The Figure 1 Below illustrates the prototype concept and the scenario where various sensors are deployed inside a home to detect different phenomenon.

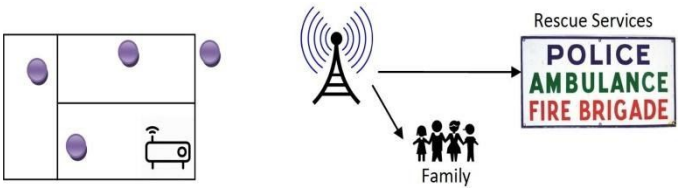

Fig. 1. Prototype Design Concept

The detected phenomenon is then processed and the information is reported further to various systems. The flowchart in the figure below illustrates the working of the proposed prototype in detail.

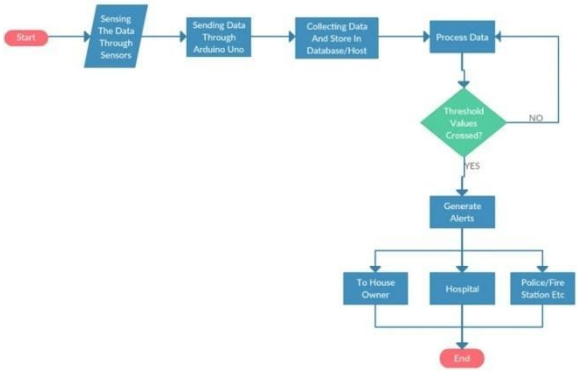

Fig. 2. Prototype Working

Each house may be equipped with a device (includes various sensors) detects the phenomenon and analyses it by comparing it with the preloaded threshold values. If the detected values exceed the threshold value, an alert is generated that is transmitted via GSM connection to three different locations. These locations/systems include sending a text message to the homeowner, Hospital and services department (Police and/or Fire Station) whereas, if the sensed values are within the range of the threshold value, the detected data is discarded. The prototype design is initially translated into simulation to help understand any issues related to the detection and communication of the detected data with the respective base station. The simulation details are discussed in the next section.

III. PROTOTYPE SIMULATION

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The aim of simulating the Smart-home scenario was to outline possible issues with respect to real-time (hardware) implementation in the next phase of the prototype implementation. This section discusses and presents details regarding the scenario under consideration and the simulation parameters used.

Design of low-cost smart-home network scenario consists of a small village with few houses and each containing at least three sensor nodes used for monitoring temperature, smoke and humidity. Network simulator (ns 3) was used for simulation design and analyses. Figure 3 below is a screen shot from network animator (nam) depicting a smart home scenario with various sensors deployed in the home environment. The sensor nodes are deployed in kitchen, room(s), lounge, etc. The black lines are a result of node initialization (at the time of screen shot).

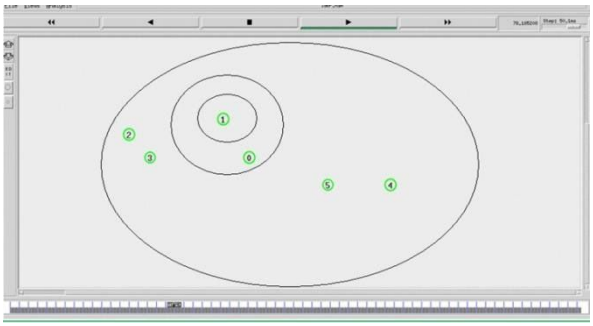

Fig. 3. Smart-home Sensor Nodes Deployment

Similarly, a second scenario where a village of 20 houses has been considered is simulated. The nam screen shot (figure below) illustrates the scenario. All houses contain 2-3 sensor nodes used for monitoring various phenomenon.

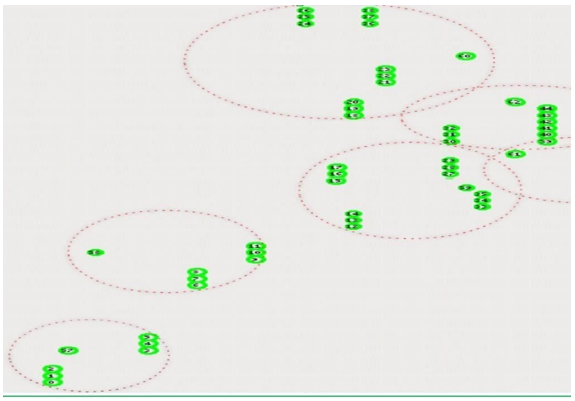

Fig. 4. Simulation of a Village

Communication delay with respect to houses being situated at un-reachable locations was analyzed. Base stations were used for sensors to owner/emergency service station communication. The nodes communicating via single base station (BS) have less delay as compared to those that are further away and communicate using 2 or more BS. The results are illustrated in the figure 5 below.

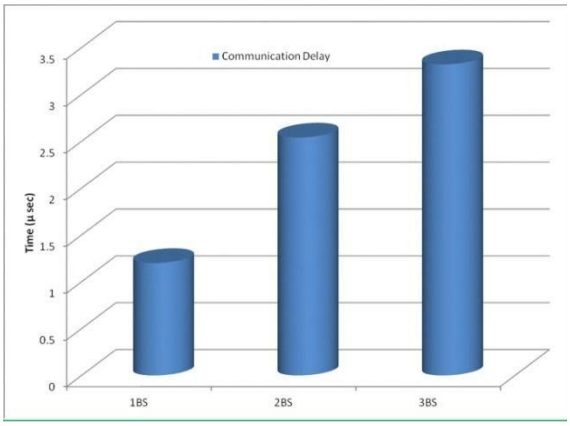

Fig. 5. Communication Delay

Simulation results highlighted the possible challenges that the hardware implementation may face with respect to the communication delay and the connection with the base station, etc. The hardware implementation is discussed in detail in the next section.

IV. PROTOTYPE HARDWARE IMPLEMENTATION

Wireless sensor network applications cover a wide variety of solutions to different problems in different scenarios.

Rural areas of Pakistan face various issues and challenges depending upon the geographical region. A rural region in south east of Pakistan may face high temperature and drought conditions as compared to the north east region where cold and humid weather may result in landslides and other issues. Hence three different sensing devices were selected for the prototype design in real time. The details are discussed below.

After a thorough investigation of the suitability of available technology with respect to vulnerabilities threats of a specific region the sensing devices of the prototype include:

- Temperature and humidity
- Smoke

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- Soil Moisture

To interface these sensors Arduino Uno R3 Microcontroller has been used [14]. The arduino details are given in the figure 6 below.

TYPE	Power Supply	O/P Signal	Accuracy	Operation Temperature	Response Time 55	Measuring Unit
Temperature & Humidity	3.3-5v (DC)	0.8-3.8 V	90%RH(0-100)	-40 To +125ºC	15Sec	% w.r.t ºC
Smoke	2.3-5.5 V(DC)	0.48V-2.34V	70% RH(0-100)	-40 To +125ºC	1.65 Sec	Heat Level/ Depend upon Programming Logic
Soil Moisture	3.3-5 V(DC)	4-20mA	80%RH(0-100)	(-40° To +55°C	1.65Sec	Moisture w.r.t RH

Fig. 6. Arduino Details

All the selected sensors help detect various phenomenon, which if undetected, may lead to a possible disaster which may result in loss of precious lives. The figure 7 below provides details regarding the selected sensors [15].

Type	Model	Power Supply	I/P Pins	Memory	Clock Cycle
ATmega328 microcontroller	Uno R3	7-12 V	14 (Digital)	32KB(Flash)	16MHz

Fig. 7. Sensor Details

Each sensor is selected as the requirement of a disaster prevention measure such as the temperature and humidity sensor (Figure 11) may help monitor extreme temperatures inside a remotely located house or a soil moisture sensor (Figure 10) may detect a possible landslide scenario near it (if the residence is located in a valley or mountain region). Similarly, the smoke detection sensor (Figure 9) may help in informing and providing timely relief in case of a fire. Nevertheless, implementation of a low-cost smart-home network prototype is considered as a centralized network to provide timely relief to rural residents of Pakistan in case of any emergency. The figure 8 below shows the photographs of the system design illustrating the prototype implementation using the hardware setup.

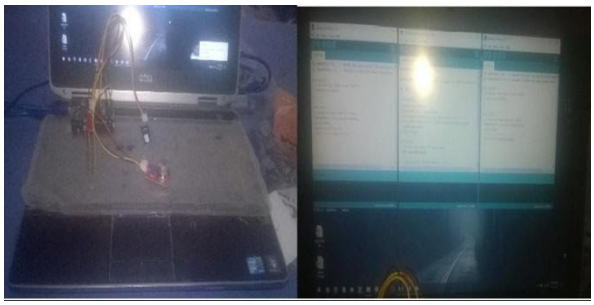

Fig. 8. Prototype Implementation using hardware setup

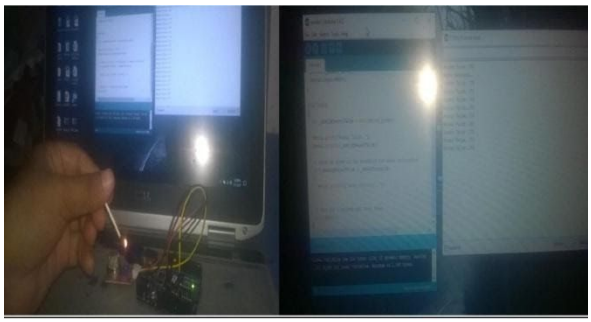

Fig. 9. Illustrating Smoke Detection

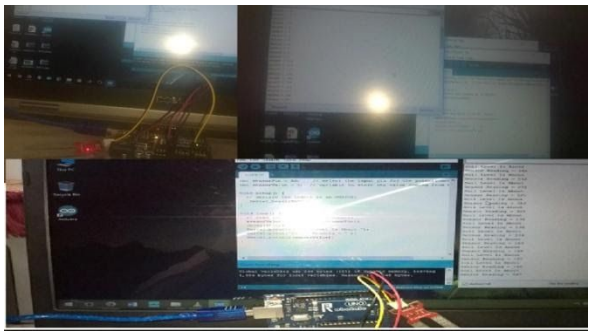

Fig. 10. Soil Moisture Detection

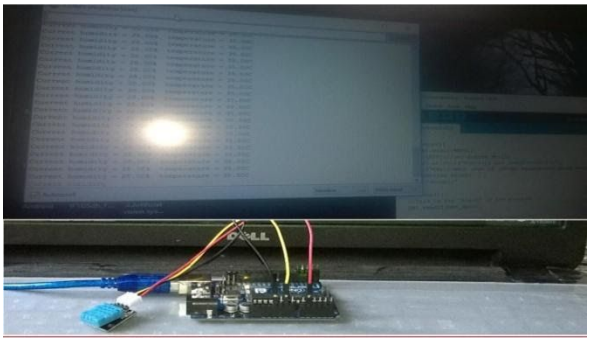

Fig. 11. Temperature and Humidity Detection

The implemented prototype showed promising results and the sensors detected the phenomenon and the overall information processed was used to send alerts and warnings to the centralized system. This prototype may be very useful if implemented in real time as a complete system on a large scale to save precious lives. The next section discusses the conclusion and future work.

V. CONCLUSION

A low-cost smart-home network to provide comfort and timely relief to the residents of rural areas under consideration has been proposed. The prototype was designed in two phases by first simulating the smart home environment to highlight

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the possible issues and challenges for phase 2 of the proposed prototype implementation. The simulation results showed that the prototype may work promisingly if the number of base stations involved in communicating the alert were less. The second phase included a hardware implementation in real-time environment using sensing devices and Arduino. This proto- type may help provide timely relief in the remote areas (rural areas) of Pakistan in case of mishaps such as fire, extreme temperatures, landslides, etc. The future work includes actual implementation of the proposed prototype with the help of sponsoring NGO (underway). Nevertheless, more features and functionalities may also be added to the proposed prototype such as solar energy for home lighting and CO2 detection, etc.

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