WiEyeTNB: A Wireless Sensor Based Drowning Detection System for Enhanced Parental Care

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Abstract. Drowning is considered as the third leading cause of unintentional injury death globally. In many low and middle income countries drowning is one of the leading causes of death, especially for children under 12 years old. According to the World Health Organization (WHO) report 388000 people died in 2004 as a result of drowning around the world. The overall global rate of drowning among children is 7.8 deaths per 10000 populations. Advances in sensing devices and integrated circuit technology pave the way for many smart sensing products. WiEyeTNB, Wireless Eye That Never Blinks, discusses the novel notion of designing a smart sensor product for detecting drowning in advance, especially among the children under the age of 5. Smart sensor devices consist of a microprocessor, RF transceiver, one or more sensors and powering devices. The proposed system issues an alarm through a wireless network so that immediate attention can be given to the casualty. Simulation of the system is performed using QualNet 5.0.2 Network Simulator and evaluated the performance of the proposed system architecture.

Keywords: Drowning, Wireless Sensor, Unintentional Death, WiEyeTNB**,** QualNet Simulator.

1 Introduction

This work started in view of the ever increasing death due to drowning especially in low and middle income countries. Children under 5 years of age have the highest drowning mortality rates worldwide [1]. In 2004, drowning took the life of approximately 175 000 children and youth under the age of 20 years around the world. Out of which 98.1% of these deaths registered in low-income and middle-income countries. The lack of direct adult supervision, even for very short periods of time, is the main cause in most of the drowning deaths of children under the age of 5. Causes may vary for other age group children. In general males are more prone to drowning than females. This may be due to increased exposure to water and riskier behavior of males. This paper concentrates on the unintentional drowning death of children especially under the age of 5.

P. Ren et al. (Eds.): WICON 2011, LNICST 98, pp. 511–520, 2012.

The proposed system, WiEyeTNB, uses a wireless sensor unit that collects process and transmits data. The sensor unit contains of a microprocessor, RF transceiver, one or more sensors and powering devices. The sensor unit is designed as a light weight wearable ear-ring so that it comes in the same level as the mouth of a human being. Water level crossing the mouth level can be dangerous and causes respiratory impairment that even leads to death. Therefore identifying an event, in which water reaches the mouth level, in advance through the sensors equipped along with the ear-ring helps to provide an early alarm to avoid unintentional drowning.

The sensor unit in the form of an ear ring detects the presence of water when the water-detecting sensor senses the presence of water. A high probability of drowning event is detected if the sensor unit detects the presence of water above a predefined threshold level. Data collected by the sensors are analyzed and issue an early alarm to avoid the child from drowning. The sensor periodically monitors the presence of water beyond a predefined threshold limit, and issues an alarm if the water level crosses the limit.

2 Related Works

2.1 POSEIDON Computer Aided Drowning Detection System

The Poseidon system is an intelligent system that uses proprietary computer vision technology to help provide constant surveillance [2] of the water pools and monitor the trajectories [3] of the swimmers. Cameras are mounted under the water in the walls of the pool for deep water or overhead to monitor shallower areas. All these cameras give a complete and overlapping view of the swimming pool. The network of all the cameras monitors swimmers in the pool in real-time. The images captured by the cameras are analyzed by the central processing system of Poseidon system. When the system detects a swimmer in difficulty, it issues an alarm so that the life-guards can attend the casualty. The system alerts lifeguards via a LED display or mobile phone or a pager and a supervision workstation within 10 seconds of the occurrence of the drowning activity. The workstation provides a way to provide and visualize the operation of the system. The user interface associated with the workstation allows operators to view and see the alerts when they happen. Real-time video images of the incident and its location are displayed and recorded immediately on a supervision workstation.

The Poseidon system is intended to complement lifeguards, not to replace them or reduce their responsibilities or vigilance. Under no circumstances should the presence or use of Poseidon result in the reduction or modification of lifeguard staffing or duties as required by regulation or normal practice.

2.2 SACUNDA Pool Security System

SACUNDA is a swimming pool safety vigilance system for preventing children from drowning. It’s a unique state-of-the-art technology designed to alert parents and caregivers of potential drowning by creating an invisible ever present underwater passive “acoustic net” [4] below the surface of the water. When a child falls into the pool, acoustic net is broken immediately and send distinct signal to alert parents or guardians. SACUNDA system can send a response in less than 1 second in case of event detection. SACUNDA is not a system to replace parental care but to assist them to save lives in case of accidental drowning. In SACUNDA, sensors placed underwater act as invisible acoustic net. These sensors are capable of detecting intrusions in the form of drowning children.

The main components of SACUNDA are underwater sensor, command station, control panel and a remote control. The underwater sensor is used to detect acoustic energy in the water. The sensor is also capable of taking pictures of underwater acoustic energy. Analysis of the acoustic energy is done by a dedicated digital system equipped with specific DSP software. SACUNDA's central processing unit analyses the acoustic pictures received from all the sensors inside the pool in real-time. When SACUNDA detects an intrusion similar to a six year old baby, it sends a wireless alarm to the control panel. The control panel controls the main operations of the system.

A simple user interface associated with the control panel helps the parents to view the system status and alerts when it happens. A remote control, a hand-held wireless transmitter, is used for shutting down the siren from a distance, if needed.

3 System Design

Fig.1 shows the overall system architecture of WiEyeTNB. The architecture is based on the assumption that drowning happens in the premises of home or school due to the lack of attention from the adult, may be teachers or caregivers. WiEyeTNB is not an alternative to parental care; rather it assists parents or caregivers to understand drowning in advance and thereby avoids causality due to drowning.

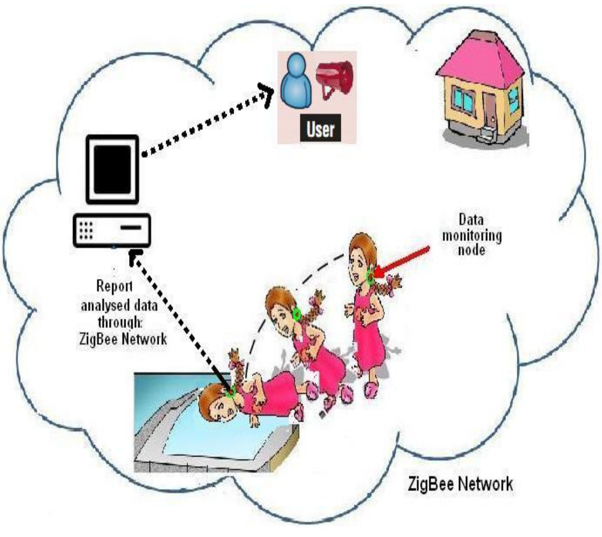

Fig. 1. WiEyeTNB Overall System Architecture

WiEyeTNB concentrates on the unintentional drowning death of children especially under the age of 5. The child to be monitored has to be equipped with a sensor unit in the form of an ear-ring. The sensor unit is designed as a compact one, so that it can be easily wearable even for a small child.

A ZigBee network monitors the area where the home or school is situated. The water-detecting sensor fixed in the form of an ear-ring detects a drowning event when it happens and sent the message to the processing unit through the wireless network. Then an alarm is issued so that immediate attention can be given to avoid drowning.

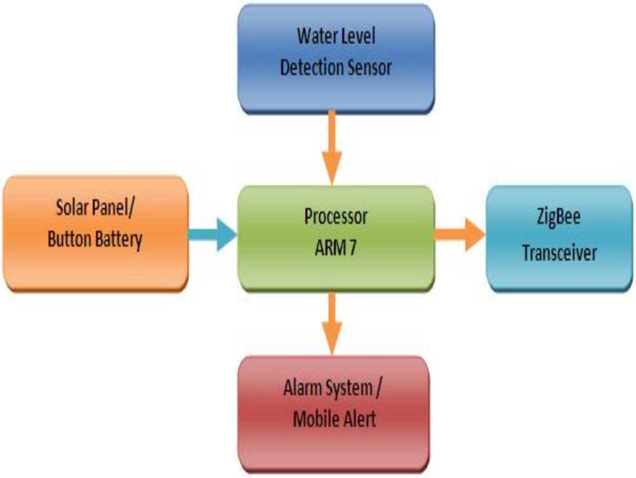

Fig. 2. WiEyeTNB System Design

The architecture of WiEyeTNB is based on five main components: water-level detection sensor, central processing unit, ZigBee transceiver, powering unit and alarm unit as shown in Fig 2.

3.1 Water-Level Detection Sensor

Water-level Detection Sensor is the principal component in the sensing unit of WiEyeTNB. This sensor detects the presence of water when the sensor comes in contact with water beyond a threshold limit, W_T. The threshold water limit is set in order to avoid false alarming. Fig. 3 shows how the sensor unit detects the presence of water, in case of a drowning event, and issues an alarm.

The water-level detection sensor continuously checks whether the sensor comes in contact with water beyond a threshold water level, W_T. If the sensor finds the current water-level is beyond W_T then the system issues an alarm. The alarm helps parents or caregivers to know about the potential threat and take necessary steps to avoid drowning. The sensing unit also contains of an Analog-to-Digital Converter (ADC). The analog signals produced by the sensors are digitized by ADC and sent to the processing unit for further processing.

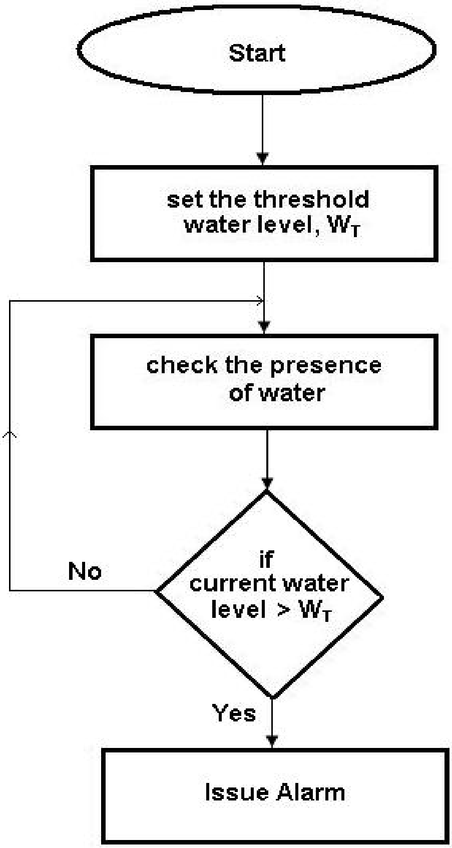

Fig. 3. WiEyeTNB Event Identification

3.2 Central Processing Unit

The Central Processing Unit (CPU) mainly consists of a microcontroller/microprocessor associated with a small storage unit including on-chip memory and flash memory. The processing unit is responsible for performing tasks, processing data and controlling the functionality of other components of the sensor node. A wireless system architecture demands the processor to do all the necessary computing capability coupled with low power consumption. Moreover the size of the processor should be compact in nature and thereby less costly. WiEyeTNB uses such a processor, an ARM 7 processor, in its design.

3.3 ZigBee Transceiver

The wireless sensor unit communicates with the alarm unit via a ZigBee wireless transceiver. The 802.15.4 standard specifies the physical layer and medium access control for low-rate. Low-cost wireless communications whilst protocols [7] like ZigBee is build upon this by developing the upper layers of the OSI Reference Model. Wireless sensor communications tend to operate in the RF industrial, scientific and medical (ISM) bands which are designed for unlicensed operation.

ZigBee in the 2.5 GHz ISM band having a data rate of 250 kbps offers an outdoor range close to 100 meters. WiEyeTNB is designed for monitoring children in the premises of homes or schools. As an initial design of the system, a ZigBee network is setup for covering the home or school premise. The features such as reliability, self healing, easy deployment, very long battery life and low cost made WiEyeTNB to use ZigBee as the wireless standard.

3.4 Powering and Alarm Units

The main type of power supply for wireless sensor nodes are batteries, either rechargeable or non-rechargeable. Normally energy [5] is consumed for sensing, data processing and communication. WiEyeTNB demands a light weight battery since the sensor node has to be made in the form of an ear- ring.

When an alarm condition occurs, the signal is received at the alarm unit through the ZigBee network. The alarm unit consists of an electric bell that is activated upon receiving the message from the central processing unit after analysing the data captured by the sensor.

4 System Performance

For the performance study of WiEyeTNB QualNet 5.0.2 network simulator has been used. Performance of the system is analyzed and tested for various terrains and path loss models. Path loss models such as free space, suburban, irregular terrain are used for simulation. The simulation time was set for 300 seconds.

In an effort to evaluate the performance of WiEyeTNB we have developed a few simulation scenarios using QualNet. These scenarios were designed to target WiEyeTNB performance under specific terrain models such as free space, path loss and irregular terrain. The scenario dimension is set as 100 x 100 m^2. Fig. 4 shows the initial simulation setup having properties such as channel (single) frequency 2.4GHz, path loss model two-way type and non-fading model.

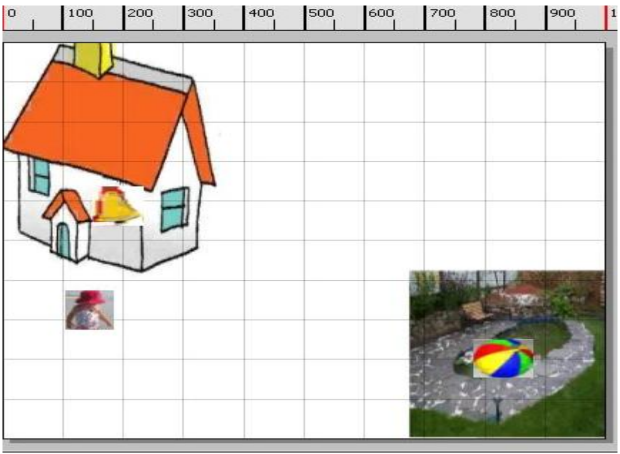

Fig. 4. Initial Simulation Setup Using QualNet 5.0.2

Fig. 5 shows the various stages of a specific simulation process. Image 1 shows a child moving towards a pool to pick her toy ball. Image 2 depicts the drowning event. The sensor unit identifies the event and issues the potential danger to the processing unit is shown in Image 3. The processing unit issues a warning alarm to the caregiver, shown in Image 4.

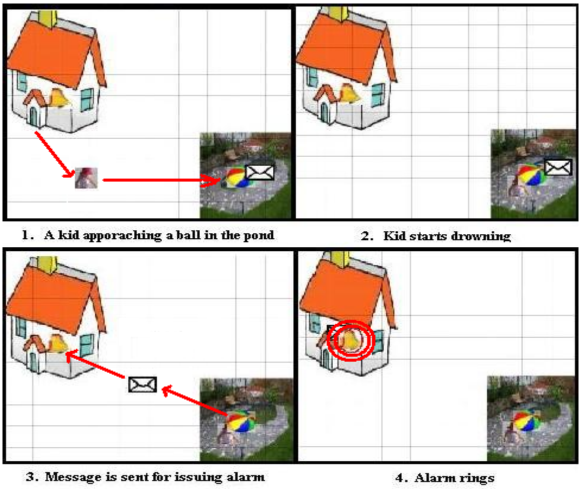

Fig. 5. Different Simulation Stages Using QualNet 5.0.2

The simulation results show that the system could issue a successful alarm, within an area close to 100 meters, even when the terrain is free space, path loss or irregular. The simulation is performed for a specific duration, 300 seconds, for the three different terrains.

Fig. 6 shows the packet analysis of the simulation of WiEyeTNB. Packets sent and received for three different terrains are analyzed. No considerable loss of packets are noticed when the terrain is changed from free space to path loss or irregular. Therefore WiEyeTNB performs well and issues an alert irrespective of the environment in which the system is deployed.

5 Challenges and Future Work

Being a wireless sensor related system WiEyeTNB has to overcome lot of challenges. Out of which the radio range of the wireless network has got prime importance. The child under monitoring should be inside the radio range of the wireless network. The ZigBee network provides an outdoor range close to 100 meters. This might serve the surveillance of the premises of homes better; repeaters must be used in case of schools with large premises to get additional range.

Increased vegetation in the environment has an effect on the received signal strength. That may sometimes cause no alarming or even false alarming. Apart from that multipath loss [6], absorption loss, diffraction loss and atmospheric loss have influence on the signal strength.

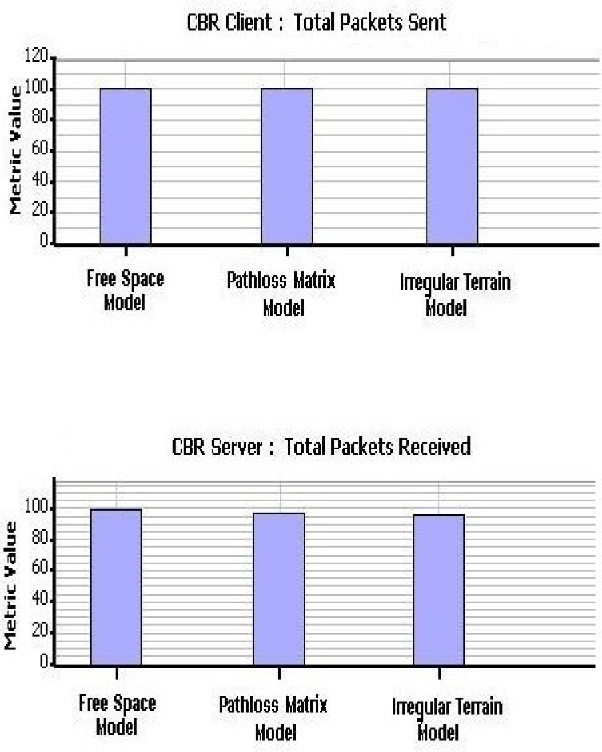

Fig. 6. Packet Analysis of WiEyeTNB Simulation

The most general empirical model for path loss is given as follows:

$$L_1(d) = L_0 + 10\ c\ \log_{10}(d) \tag{1}$$

where L_0 is called reference point loss and represents the loss value at one meter distance away from the transmitter, c is the path loss component depending on the environment, d is the Euclidian distance (in m) from the transmitter. Parameters L_0 and c have been determined for various environments through empirical studies for possible values of L_0 and c in various environments.

Another major challenge associated with WiEyeTNB is the design of the compact sensor unit. The sensor unit is designed to be in the form of an ear-ring which is light-weight in nature. Various tradeoffs can be made in selecting suitable components for the sensor unit to make it compact. In wireless sensor networks although the average current consumption of a sensor unit is low, the instantaneous current can be high. This instantaneous or peak current consumption can have an adverse effect on the battery's actual capacity. In WiEyeTNB the sensor unit which is in the form of an ear-ring is made as a detachable device. It needs to be worn only when the child goes to places that need to be monitored. Therefore the battery can be recharged when the device is not in use. This helps in selecting light-weight battery that suits the compact design of the sensor unit.

An emergency alarm only need not avoid a potential casualty unless the location of the child is not known. Future work will be concentrating on having a simple user interface at home or school office so that the display helps the parents or caregivers to view the position of the child. A GPS module has to be included in the sensor unit to keep track of the child in the region.

By increasing the radio range of the network, WiEyeTNB can be used for monitoring children in large areas. ZigBee is a low tier, ad hoc, terrestrial, wireless standard in some ways similar to Bluetooth. The IEEE 802.15.4 standard is commonly known as ZigBee, but ZigBee has some features in addition to those of 802.15.4. It operates in the 868 MHz, 915 MHz and 2.4 GHz ISM bands. Even though ZigBee has features such as reliability, self healing, easy deployment, very long battery life, low cost etc, the range it offers is less compared to the other competitive standards. The maximum outdoor range of ZigBee is around 100 meters. Future work will be looking into wireless standards such as IEEE 802.11a/b/g/n in order to compensate the low outdoor range of ZigBee network.

A better range and an improved data rate will always enhance the effectiveness of any wireless system. Table 1 shows the comparative study of various IEEE 802.11 standards. Incorporating the advanced wireless standards like IEEE 802.11 g/n will widen the scope of WiEyeTNB. In future WiEyeTNB can be used for monitoring children in wide range of areas like parks and beaches.

Table 1. IEEE 802.11 Radio Classifications

Characteristics	IEEE 802.11 b	IEEE 802.11 a	IEEE 802.11 g	IEEE 802.11 n
Frequency	2.4 GHz	5 GHz	2.4 GHz	2.4GHz / 5 GHz
Data Rate	11Mbps	54Mbps	54Mbps	150Mbps
Indoor Range	38m	35m	38m	70m
Outdoor Range	140m	120m	140m	250m

6 Conclusions

WiEyeTNB is a system to aid the parents and caregivers to enhance the care given to children especially from drowning. The existing systems are purely based on surveillance cameras. Such systems need large number of monitoring cameras, high computing processors and huge storage space. WiEyeTNB is based on wireless sensor technology which is economical and does not demand high commutating processors. Moreover a single sensor replaces the need of any number of monitoring cameras which are costly in general. The system performance is analyzed for various terrain as well as path loss models. WiEyeTNB offers accurate alarming even in high vegetation environments. WiEyeTNB's range is limited to monitor a normal home or school premise. Incorporating wireless networks that offer high outdoor range can revolutionize the monitoring range of WiEyeTNB. Still WiEyeTNB resembles the quote "an ounce of prevention is worth a pound of cure".

Acknowledgments. We are grateful to Amrita University for providing an ambience where research and innovation are celebrated as a way of life. We are also thankful to our Chancellor Mata Amritanandamayi Devi who taught us the importance of doing research that aims to uplift the needs of the society.

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