Computers and Electrical Engineering 62 (2017) 44–52

Contents lists available at ScienceDirect

Computers and Electrical Engineering

journal homepage: www.elsevier.com/locate/compeleceng

A gradient sensing middleware to handle flash flood[☆]

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A R T I C L E I N F O

Article history:
Received 28 September 2016
Revised 10 August 2017
Accepted 10 August 2017

Keywords:
Flash flood
Middleware
Internet of thing
Solution for natural disaster in Bangladesh
Low cost distributed System
Flash flood prevention

A B S T R A C T

Flash Flood is a natural disaster that floods away large area in a sudden manner. Bangladesh is affected by this natural disaster and loses valuable assets regularly. We currently have developed a system that has cloud infrastructure for intelligent long term data processing and low cost sensing devices that are able to make local decisions in its surrounding area. The system is adopted to work in a developing country such as low cost sensing that is locally available along with ability to adapt to sparse network infrastructure. Our system is called Shonabondhu: Golden Friend in Bengali, and we share our design, development and evaluation cycle of this system.

1. Introduction

Our advancement in technology is not reflected when we are going back to a third world country fighting natural disasters often. We have considered Bangladesh as our field of study and we consider the problem of Flash Flood. Flash Flood occurs when the river water level rises rapidly within a short period of time (often within 2 hours water level can rise as high as few meters) mainly caused by sudden heavy rainfall in locality. It is a major problem in many different countries like Bangladesh, India, China, Nepal, Malaysia, Philippines and many other countries [1,2,3]. It must be mentioned that the low area that are flooded by the flash flood are used for fishing through the monsoon season and living with this periodical presence of water is part of the lives of people residing in our low land area (Haor Area, called in Bangladesh). People are generally aware of the water lever rise in monsoon season—the problem lies in the sudden nature of water level increase. Residents of Haor area have mentioned that they would be greatly benefited if they could have an earlier warning. The current water level measurement systems are manual where dedicated personnel go out to measure the water level which has its shortcomings of missing the critical time to warn people with enough time to prepare.

There have been an array of research studies that consider water level sensing, monitoring and /or prediction and offer valid system support for deployment of such system. Elizabeth et al. [4] have worked on water monitoring system deployed at Honduras, a river in Massachusetts using a predictive sensor environment; Stoianov et al. [5] used sensor network to monitor Boston Sewer Commission Data, Sunkpho and Ootamakorn. [6] used real time flood monitoring system deployed at Thammarat a Southern province of Thailand; Hughes et al. [1] used sensor based system to study flood monitoring system

☆ Reviews processed and recommended for publication to the Editor-in-Chief by Associate Editor Dr. Tie Qiu.

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http://dx.doi.org/10.1016/j.compeleceng.2017.08.006
0045-7906/

on the River Ribble in North West England (Details of our discussion will be found in related work section). The major difference lies in the problem scopes. In the cases of previously conducted studies—a single river and river bank is studied. When the geographic location is closely situated—a light weight solution like wireless sensor network based architecture can be an excellent solution as we have seen in many existing systems. In Bangladesh, however, we have a network of rivers that contribute to the flash flood problem. Our water monitoring system must include various locations that are geographically distant. We need a solution that is able to study the water level, consider history data and is very responsive so that real time alerts can be generated that is coherent with the river water flow system. We also have to focus on a solution that is low cost i.e., that exploits existing network infrastructure along with low cost, locally available sensing devices.

We have been working on the Flash Flood problem from 2012 [3,7–9] and have modified the system based on environmental challenges, available resources and low cost considerations which we share in our research work. Our system Shonabondhu (Golden friend, in Bengali) is a middleware system that uses cloud infrastructure, long term learning decisions at server level and uses Internet of Things (IoT) devices enabled with sensors that have path abstraction to communicate among sensor modules and decision making capability to locally disseminate warning messages. We have used the network available for mobile phone communication which is rich in terms of coverage in our country. We have designed the system, developed it and deployed it for experimental purposes in few sites of Bangladesh. We are in the process of actual deployment of sensing system with the collaboration of the Water Development Board of our country.

Shonabondhu consists of servers which are assigned a gradient information as a function of its current state in terms of local water level, rainfall along with historical information for that region regarding that particular time of year. These servers are called gradient servers and these servers collect information from the sensor nodes and process them. If for any environmental factor, the gradient information changes in a server—it will propagate that information to interested servers which may be affected by the change of that particular server. And the gradient information may be changed in cascading fashion accordingly. It can be the case where a gradient server near the source of the river experiences sudden rise of water level and as electrons travel faster than any physical entity, we can expect that server to propagate that water level rise information to other servers along the connected river system and if certain thresholds are crossed, adequate alarms can be generated. We have also considered a webserver that will act as the spokesperson for the entire system and will be responsible for doing long term data analysis unlike the local servers. In our infrastructure, we have considered the central server to be part of a cloud for resilient and reliable performance. At the lower level we have IoT devices with processing capability and communication capability to make locally intelligent decisions. For example, a sensor node will bundle up water level information over few reading when the water level is stable and far below from the danger level. Once the water level starts to rise, it will increase the frequency of message dissemination along with communication to the local authority. We have published several parts of our incremental work previously [3,7–9] and here we have the IoT sensing system presented which has not been published previously. It must be noted that the paper does not work on the hydrological aspects of flood monitoring system—it uses terminologies provided by the water development board, Bangladesh such as danger level and water level and works accordingly. Specifically, our contribution lies in the following areas:

- Design a distributed sensor system using gradient information learned from previous sensor data
- Extensive study on individual sensors and modularized test in laboratory as well as in outdoor setup
- Design and development of IoT Sensing system that can make local decisions
- Study of simulation environmental setup using Cloud in case of heavy or light load of sensor generated data

The rest of the paper is organized as follows: we discuss the related work in Section 2, followed by background in Section 3. We discuss about our proposed system in Section 4, evaluation in Section 5 and finally, the conclusion and future work is presented in Section 6 in consecutive order.

2. Related work

We have looked at works that are similar in concept with our research in many different ways: existing work on water level sensing, disaster sensing mostly uses wireless sensor network as infrastructure and we have consulted existing state of the art work, there are some work from different research studies that use the concept of gradient sensing works but in different context. At the same time, our path based communication has been inspired by some previous work which is illustrated here in the following discussion.

Elizabeth et al. [4] have worked on a deployment that covers Honduras, a river in Massachusetts using a predictive sensor environment. It uses a two tier approach to minimize cost—some nodes work in long range using radio signal while other nodes work for shorter range. It uses three sensor nodes for testing purpose to cover the particular river of interest. Sunkpho and Ootamakorn [6] discuss about a real time flood monitoring system. It is installed to monitor Nakhon Si Thammarat, a southern province of Thailand where flooding is a recurrent event. It uses sensing monitoring in 15 sites using internet based real time monitoring. The middleware named VitualCom is in charge of communication among sensors and Application Server. Stoianov et al. [5] used sensor networks to monitor water supply and sewer system. This system uses wireless sensor network to cover the area of interest. It is used at Boston Water Sewer Commission and it collects water level information in real time. The remote monitoring system uses high data rate sampling which is 1000 samples per second. The entire system is based on Wireless Sensor Network (WSN). LooCI System [1] developed by Hughes et al. focuses on a novel component binding model using even binding a wireless sensing system. It can be a good candidate to implement