Jalli: System Level Support for Critical Real-Time Applications

Nova Ahmed
Design Inclusion and Access Lab (DIAL), North South University
Dhaka, Dhaka, Bangladesh
nova.ahmed@northsouth.edu

Rahat Jahangir Rony
Cardiff University
Cardiff, Cardiff, United Kingdom
RonyR@cardiff.ac.uk

Md. Majedur Rahman
Independent Researcher
Dhaka, Dhaka, Bangladesh
majedur.rahman.mmr@gmail.com

Abstract

System level support is required for modern day Internet of Things (IoT) based applications. It opens up opportunities for low-cost solution approaches. We have developed a system solution for real time IoT based applications that allows real time access to location information and allows level of data abstraction for tracing location to be used in emergency situations. We have developed a wearable IoT solution to deal with the problem of sexual harassment on top of the system named Jalli. The application considers a developing country context. We hope that a system that is aware and sensitive about the resource limitations can bring out best possible system performance in the context of low resource regions.

CCS Concepts

• **Human-Computer Interaction → Ubiquitous and Mobile Computing Systems and Tools**.

Keywords

IoT, Harassment solution, Low cost Computing Solution

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1 Introduction

Low-cost Internet of Things (IoT) enabled solutions for various problem spaces have shown promises for developing regions. There are requirements for location centric system support where individual user's privacy must be preserved. We have looked at a real time location system that facilitates users during an emergency, from a developing country context. We have particularly considered the problem of sexual harassment and the system level support such system may require. The system support must enable user's location for trusted contacts abstracting it from others where location information might place the individual in vulnerable situation. A system level support can enable best application development opportunities for real time system design. Sexual harassment is a global concern [4, 12]. Recent online movements show the intensity of the problem at global scale. The problem is more challenging to work with, in developing countries. There are social cultural barriers where women do not want to discuss about the problem [1]. Technology based solution to establish social justice inspires the current work [2, 3, 5–7]. Our research work presents a system solution to enhance personal safety and connectivity required in adverse situations.

Technology enabled safety measures can support users to seek help. Tech-solution can be used to keep trace of a person. The call for help and traces of information can improve ways to support a person in danger. However, location information impacts one's privacy. Location information places one in vulnerable position if it is exposed to the wrong place. It is challenging to balance personal safety and privacy requirements. We focus on a solution approach that keeps user information in a secured manner to support personal safety.

In many countries, personal safety is a concern due to ongoing instabilities. We take a look at one such region where real time support and/or ability to track one's last location can be crucial ensuring trusted elements in the system. Here violence against women and sexual harassment are also ongoing problems. The work is developed in the context of Bangladesh. There has been ongoing work focusing on safety of women against sexual harassment: through collective effort creating a virtual community [5–7]; utilizing the power of crowdsourcing [3] and individual efforts of asking for support through technology interfaces [2, 10]. Technology has enhanced reachability in regions where emergency support services such as 911 emergency call in USA are limited or not available [11]. An in-depth user level study has explored requirement for a solution that can support a user seeking safety in physical environment. An application level solution approach can provide support for the person seeking immediate help as has been studied in previous systems. On top of that, a system level design approach enables a solution that is robust and scalable.

Mobile phone penetration is high in Bangladesh. A solution to deal with personal safety can take advantage of available mobile phones. It can use a trigger to ask for help during an adverse situation. The phone's trigger can be a software trigger (e.g., touching a button in an application); a hardware activity based trigger (e.g., shaking of a phone) or an external trigger (e.g., a wearable device that talks to the phone). We have considered the low-cost Internet of Things (IoT) based trigger to seek help. The choice of wearable was considered from a public harassment during Bengali New Year [8]. It took place during the crowded celebration point. Mobile phones were not easily accessible for women at that time. Our major contribution lies in designing a system to support such trigger based application. The system will work for other trigger based applications as well.

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We have conducted our study on our own system based on availability of hardware and low-cost. Our system is publicly available for free usage. Current emergence of Internet of Things (IoT) technology created requirement of system considering heterogeneous components, data collection challenges, being able to make context sensitive decisions [9]. Applications requiring real time responses have IoT system that are aware of the specific design challenges [1]. Many IoT systems are not equipped to handle scenarios where infrastructure limitations may be present. In developing countries, there are limitations such as scarcity in internet connectivity. A system should take advantage of the currently available components in the presence of resource constraints. The other problem is in urban context dealing with real time support in presence of a problem such as physical harassment/sexual harassment.

Jalli is designed to support low cost IoT sensing allowing real time response system as well as long term analytics. A wearable device is triggered by touch in the presence of adverse situation. On a trigger, mobile phone application sends out SMS messages for help. SMS messages work are not restricted to internet connectivity or smart phones. SMS messages reach to the group user has paired up as user's trusted community. The connection to the trusted community takes place through a two-way authentication phase only once at installation time. If internet is available, the system stores the time (timestamp) and location information of the victim in cloud. This trail collection part is named cookie-crumb that stores timed traces as was done in a fairytale. The trails are only visible to the trusted community. In the presence of an adverse situation, the supporting community can immediately reach the user for help. In conditions where the user or user's device may be removed from the situation, others can use the trails for further investigation. Our system uses device level security and component security along with secured device pairing at system level. The time stamped real-time response management system is a unique feature of this system. Jalli considers opportunistic connections for cloud storage updates considering the sparse internet connectivity. The focus of the current work is on the harassment support system as an application which uses IoT wearable sensor as a trigger, mobile phone application as a communicator device utilizing the features available through Jalli.

Specifically, the contribution of this work lies in presenting the following: (1). A system named Jalli and its architecture is presented to handle real time applications that can be used in emergency situations. (2) Deployment of an application system using Jalli to manage safety and privacy from personal safety context.

The study was approved by IRB committee of the university.

1.1 Participant Recruitment Method and Analysis

We conducted two different studies. The participant details and study methodologies varied across time and participant requirements as presented in Figure 1. During the interviews one researcher would act as a moderator while the others took notes. The moderation was done in the native language of the participants to facilitate proper communication. Snacks were arranged for each participant as a token of appreciation for their participation. Audio recordings of the interviews were transcribed to English language and served as raw data. Inductive analysis method was then used to analyze these data. Multiple researchers coded the same interview to ensure consistency of the findings.

Gr.No.	Discussion Type	Participant Gender and Validation
G1, N=30	Individual Interview, Snowball sampling	To understand initially about existence of sexual harassment. **30 Female. No Male**
G2, N=121	Online Survey, Students & working community.	To understand about sexual harassment over a wider community. **79 Female. 42 Male**
G3, N=10	Focus group discussion. Tertiary students.	Deeper understanding of the problem and impact. **10 Female. No Male**
G4, N=10	Focus group discussion. Tertiary students.	Deeper understanding of the problem and impact. **10 Female. No Male**
G5, N=10	Focus group discussion. Tertiary students.	Deeper understanding of the problem and impact. **10 Female. No Male**
G6, N=60	Focus group discussion. Tertiary students.	Students in a classroom showing uneven gender balance. **10 Female. 50 Male**
G7, N=52	Online Survey. Tertiary students.	Participation was open to all gender participant.**13 Female. 9 Male**

Figure 1: Participant Details

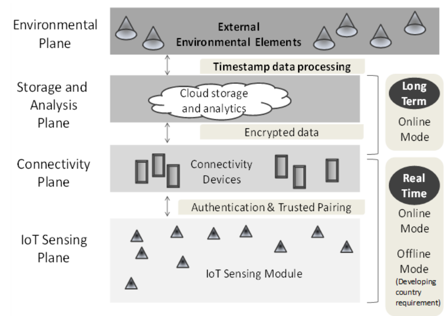

Figure 2: System Architecture

1.2 Findings

Findings from user studies helped us to formalize the problems, requirements to solve the ongoing challenges that would influence the design and solution approaches.

2 System Architecture

The system operates in different places as shown in Figure 2.

Sensing plane comprises of low cost IoT sensors which limited compute and communication capabilities. The IoT sensors are in change of continuous data dissemination to the elements of connectivity plane doing the following tasks:: Self-authentication; Trusted Pairing with Communication Layer and Real time Alert Generation.

This plane consists of distributed system elements that have compute capabilities to sensing nodes as well as server (cloud server) nodes. In the current architecture, available mobile phones are considered as connectivity elements where a distributed system deployment could incur great infrastructure burden. There particular responsibilities taken care at this plane as follows: Authentication of IoT devices; Encryption Prior to Data Delivery and Real-time Decision Making that considers the set of incidents under an alert situation.

This element is in charge of storing data in a timestamped database which allows data analysis, statistical decision making and if required, connectivity towards other external environmental elements such as CC-TV data in that region. The series of tasks conducted in this plane are shared as: Encrypted Data Storage; Cookie-Crumb Storage which keeps series of timestamped data with location and other information defined by the application.

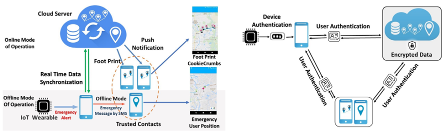

Figure 3: (Left) Deployment (Right) Communication

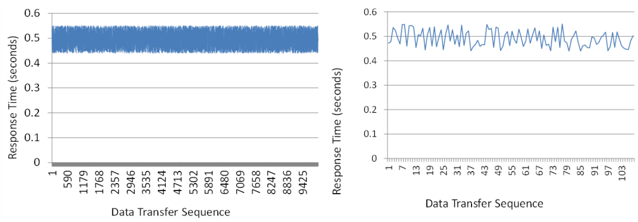

Figure 4: Cloud Response Time (Left) Over 10000 Messages (Right) Over Limited Messages

There is a consideration of offline mode of operation and online mode of operation.

3 Implementation and Evaluation

The deployment of the system along with its communication is shown in Figure 3.

3.1 System Evaluation

We have conducted two sets of studies. Cloud Response Time Evaluation: We have conducted system level evaluation where over a period of continuous one hour time-frame there was an entire thread of alert generation initiating all the other communication through the mobile phone server towards the cloud server as shown in Figure 4.

3.2 Component Response Time Evaluation

The following measurements in Figure 5 illustrates the circuit schematic and the PCB layout of the wearable device. It uses the 555-timer IC in a stable mode to generate a fixed frequency of square waves corresponding to an ASCII character, triggered by a switch. A push to the switch would activate a trigger connected to a Bluetooth module and sends the signal to our existing mobile phone Application. When the panic button is not pressed, the 555-timer circuit remains disconnected from power and only the Bluetooth module uses the minimal power needed to stay connected with mobile phone. The 555-timer IC only turn on when the panic button is pressed and that time the device consumes maximum power. After sending data the device turns off the 555-timer IC and turns on its vibrator when it gets confirmation from the phone.

4 Conclusion and Way Forward

Personal safety is a major problem around the world. The solution approaches to fight this problem have evolved over time. There have been different ways to attack the problem. Most of the existing approaches provided application level solutions. In this work, we have presented a solution from middleware level supporting the

Communication	Time
Wearable device to Application	2s
First Location Point Store in Cloud	1s~1.5s
SMS Received by trusted user	3s
Push Notification Received	2s
Application to cloud Server Transferred (Per transaction)	400ms~500ms

Figure 5: Component Response Time

communication in a secured manner. The middleware is called Jalli middleware. The novelty of the work lies in its way of user centric design along with middleware support. User centric design approach has enabled us to look at practical challenges faced by general people. There are infrastructure limitations of a developing country such as limited internet access. Resources are limited as we can see limited number of smart phone users. Our solution approach has considered such limitations in the system design phase. The current work is a continuous effort of numerous volunteers to achieve social justice.

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