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Internet of Things for Safe Cities

Amit Arora[1], Keshav Murthy R[2], Mayur R Patil[3], Rishabh Bhand[4], Anand M[5]

Student, Electronics and Communication, PESIT South Campus, Bangalore, India[1,2,3,4]

Assistant Professor, Electronics and Communication, PESIT South Campus, Bangalore, India[5]

Abstract: The ever increasing population along with frequent weather changes is exposing humans to a greater number of problems. This attributes to the increase in the levels of risk. The culture of risk prevention and management is increasingly widespread – also due to the huge media coverage of such phenomena – but cities are complex systems where strict planning is ineffective. Despite the efforts to minimize the risk, disasters occur all the time: in order to have a good disaster response capacity, the need of an adequate awareness of the present and upcoming situation is clear. Current trends in emergency management are going in the direction of structured data collection as a tool to improve reaction time and to allow analyses through geoinformation and geostatistics. Such a problem emerged worldwide in huge events (e.g. the Haiti Earthquake in 2010), but the state of the art lacks solutions focused on communication and designed with the aim of satisfying these requirements. The IoT project tackles this problem. Although we propose a rather general solution, we consider as a reference case study flood emergencies in an urban setting, focusing on the city of Bangalore. We target the scenario of floods as they are fairly frequent in Indian cities, whilst at the same time being difficult to manage. Our project is concerned with exchange and availability of real time information among emergency coordinators: our solution is able to help them in analyzing data retrieved from various sources and identifying problems in order to react in a timely manner. We focus on both integration and visualization: we integrate real time data from different sources (e.g. a mobile app handed out to rescuers) and visualize them in a clear and coherent map developed with web technologies, so that it is possible to immediately answer questions such as “which are the most critical areas?” or “where are the rescue teams?”.

Keywords: Internet of things, LoRaWAN, RFID, Rest API, Flask framework, OpenStreet Maps

I. INTRODUCTION

Continuous urbanization is a growing trend worldwide. Cities are home to more than half of people in the world today, and will be home to nearly 70% of our population by 2050. This growing concentration of people creates interesting opportunities, but also many challenges. An important one is flooding of urban areas. With the changing global climate, river flooding in cities worldwide has emerged as an immense challenge to urban resilience. Currently, approximately 21 million people worldwide could be affected by river floods on average each year, and that number could increase to 54 million in 2030 due to climate change and widespread urban development. In Europe, the cost of repairs from flooding are significant costing home owners and businesses £30,000 and £82,000 respectively. Not only are the repairs at high cost, but the average households are required to live in alternative accommodation for 5 months, costing £10,000. The damage that is caused by floods is correlated with the amount of warning that is given. Therefore, with the use of IoT technology and real time monitoring, the amount of damage caused could be minimised.

This phenomenon is becoming more and more frequent and critical due to both urbanization and climate change. Thus, flooding should be carefully studied and analyzed in order to (i) timely foresee its occurrence, (ii) keep under control both the flooding itself and the status of important infrastructures, (iii) timely help involved citizens, (iv) assess and count damages, (v) improve prevention and control mechanisms for the future.

Clearly, the problem is very complex and its solution requires the interplay of domain-specific competences on flooding, emergency management, civil protection, and ICT.

IoT blends together all the above competences and focuses on providing tools suitable to help civil protection during the occurrence of floods. More specifically, it supports exchange and availability of real time information among emergency coordinators and agents, so that they can react timely to any issue.

The work has been conducted rigorously and included the following steps:

- *Analysis of the problem:* This phase has been started with an in depth analysis of the state of the art for what

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concerns both the study of previous crises (not only floods but also earthquakes) and the analysis of the literature concerning crisis management. Moreover, it has included the development of a survey that has been conducted with representatives of twelve relevant organizations (Civil Protection, EPTR, and others). The result of this survey has allowed the team to identify two high priority issues: to gather information from other organizations and to be able to geolocate rescue teams.

- *Development of a prototype:* This prototype includes an Android application to be used by the rescue team members and a server-side system to be used by coordinating organizations to visualize the position of rescue teams and the information they provide through their terminals. The prototype is open source and is available on a public repository.

- *Collection of feedback:* In order to validate the project idea and the prototype, various relevant stakeholders have been asked to use the system and to provide feedback through a questionnaire. The answers have been analyzed and the improvements for the future have been identified.

II. BASIC CONCEPT OF IoT

At present, the IoT concept has been widely used in many research areas, including disaster management. IoT term was created by Kevin Ashton in 1999 and he defined IoT as uniquely identifiable connected objects using radio-frequency identification (RFID) technology. Later the definition of IoT become clearer when in 2009, the International Telecommunication Union (ITU) defined IoT as " A global infrastructure for the information society, enabling advances services by interconnecting, physically and virtually, things based on existing and evolving interoperable information and communication technologies" . In 2013, IoT European Research Center (IERC) further define IoT as "A dynamic global network infrastructure with self-configuring capabilities based on standard and and interoperable communication protocols where physical and virtual "things" have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network"

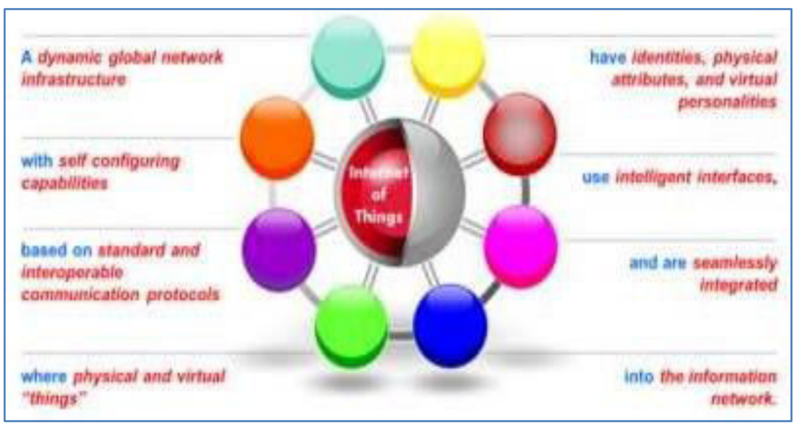

Fig 1. The IoT Defined

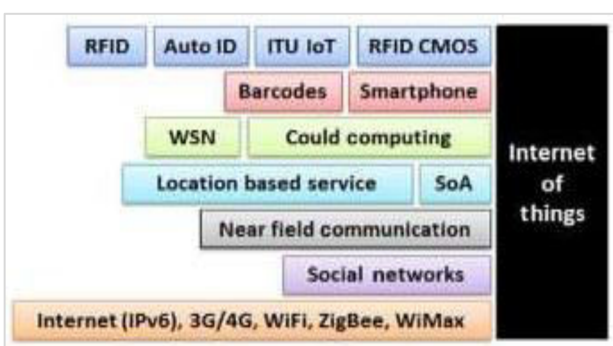

Fig 2. Enabling Technologies for IoT

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RFID is a foundational technology for IoT that allows microchips to transfer the identification information through wireless communication. Object that attach to RFID can be identified, monitored and tracked by us via RFID reader. Another technology for IoT is the Wireless Sensor Networks (WSN), which is used to interconnect intelligent sensors. The WSN applications include environmental monitoring, healthcare monitoring, industrial monitoring, and traffic monitoring. These two technologies significantly contribute to the development of IoT. Nowadays many technologies and devices such as barcodes, smart phones, social networks and cloud computing are being used to form an extensive network for supporting IoT as shown in Figure 2.

III. PROBLEM ANALYSIS

During the first work phases we framed the scope of the project and studied the relevant state of the art on risk and emergency management, mainly focusing on the procedures and laws currently in place in India. With this knowledge, we started the requirement analysis phase. To collect requirements, we contacted different organizations involved in various aspects of emergency management in the area of Bangalore, ranging from the Civil Protection to EPTR, the regional environmental agency. We were able to schedule a face to face interview with representatives from each of them. We presented them a schematic overview of the project aim and goals and asked questions that could help us to understand how they currently manage an emergency, what are the problems of the current approach, as well as to know which data can be made available to use with innovative ICT tools also in the context of partnerships with other organizations. The only mention of any subject related to flood control is drainage, water and embankment, all of which fall under the State List.

We can infer from this that the onus of flood control largely falls on the state government, while the role of the central government, according to the CAG report, is limited to providing assistance in the form of technical, advisory, policy formulation, scrutiny, clearance and monitoring of flood control to state governments. The results of these interviews were fundamental to understand the real needs of the stakeholders: it was clear that the main problem to solve is improving the communication within the agencies during an emergency, while organizations are not interested at all in investigating ways to automate the decision making process Other two high priority needs, as resulted from the interviews, are to gather information from other organizations and to be able to geolocate rescue teams: we decided to tackle them both in our project.

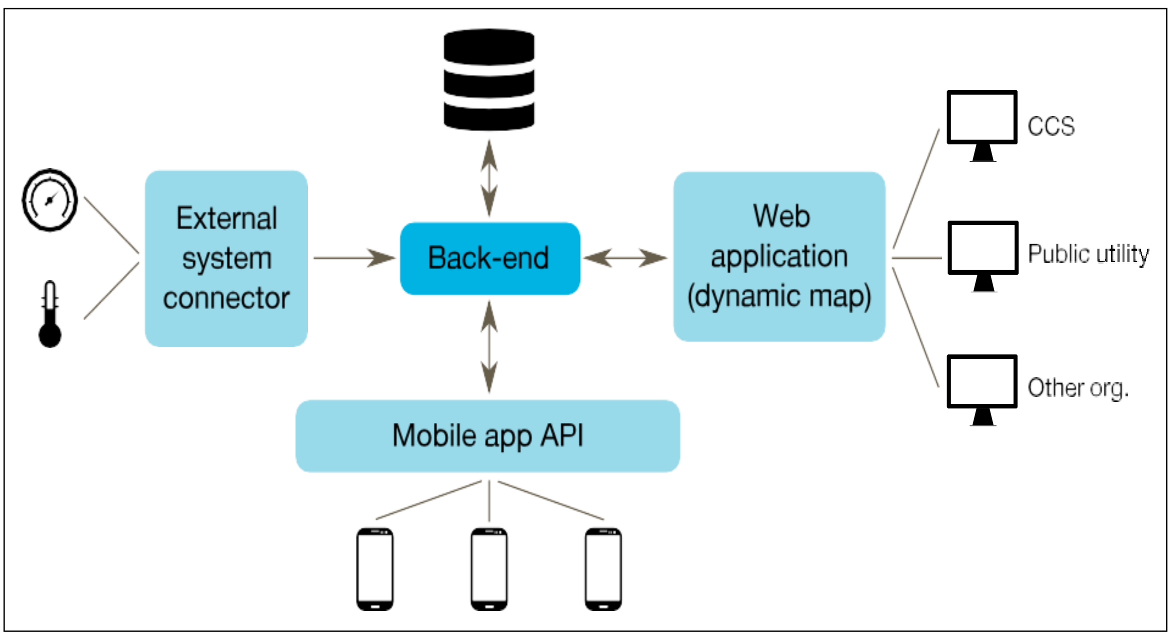

Fig 3. Conceptual Architecture

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IV. SOLUTION

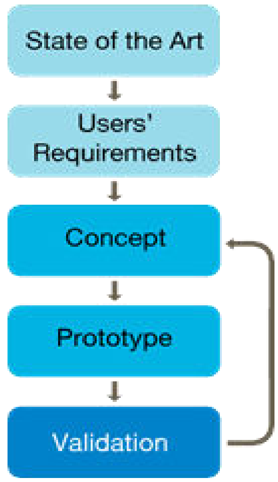

Fig 4. Flowchart of the project workflow

The outcome of our project is an ICT platform able to retrieve data from various sources and visualize them in a coherent map. Data are different in nature, both static (e.g. population density) and dynamic (e.g. rainfall and river level), collected by sensors deployed throughout the territory or pro- vided by third parties such as environmental agencies and public utilities. These sensors can be easily installed under drains in towns and cities to monitor water levels and the chance of flooding. The sensors can provide the local agencies and authorities with real-time information including alerts, early warning systems, and flood prediction within at-risk environments. This enables them to act decisively to prevent floods from occurring or at least minimize any impact.

The sensors have a long battery life and data that is collected will be transmitted over a LoRaWAN network. LoRaWAN provides long range, low-speed communication for sensors, resulting in fewer Gateway devices being deployed compared to WLAN, cellular and mobile networks. LoRaWAN provides the capability for fast, secure and cost-effective deployment of IoT smart applications across an area where large distances are involved, within urban or rural environments. Low cost sensors can be installed on bridges, grids, or culverts. The sensors will then use ultrasound to detect water surface and will then send the data securely across cutting edge technology designed for the Internet of Things. The most important feature of IoT is the ability to collect data from on field operators through a mobile application. Operators are continuously tracked by the GPS devices installed on their smartphones; they can feed the system with geolocated reports and pictures and keep track of the tasks they are assigned to. In order to aggregate and visualize data in a timely manner under all load conditions, the complete system according to the IoT concept requires a fairly high amount of computational resources. As a system designed for critical applications, it has also strict availability and reliability requirements, even if its use is concentrated in a short and unpredictable time frame. The exploitation of cloud computing features, like the ability to quickly scale up and down, is a promising solution to the problem of allocating the right amount of resources for the system. To show the feasibility of our design, we implemented a prototype that showcases some of the most important features.

It is composed by a mobile application that runs on the Android operating system (the most wide- spread one, especially on low cost devices), a REST API to allow the mobile application to send data to the server, and a web application, implemented in Python using the Flask framework, as an interface for emergency coordinators. The main part of the web application is an interactive map implemented using the OpenLayers Javascript library and OpenStreetMap maps. In order to assess the benefits of cloud computing to our project and to develop a complete cost analysis, we evaluated the resources needed by our system using the space4cloud tool. With the aid of this tool, we built a model of our system, fed with performance data obtained profiling the prototype, and we ran a set of simulations considering a realistic case study (the flood that hit Kerala in 2019) to estimate the workload pattern and the number of active users in the different phases of the crisis. We validated our idea actively involving final users: we sent to all the organizations and companies involved in the initial requirement analysis process a description of our work with instructions on how to access the prototype, and we collected their opinions. In general, organizations agreed with us that our approach can be profitably used in the real world and that it can bring a benefit, increasing the timeliness of the emergency response due to a better awareness of the situation.

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