Crowdsourcing and IoT Towards More Resilient Flooding Prone Cities

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Abstract. Crowdsourcing is a phenomenon where groups of persons sometimes from different backgrounds participate to accomplish a task by making use of technology. Internet of Things (IoT) is able to incorporate a large number of heterogeneous devices such as sensors, surveillance cameras, smartphones, home appliances, etc., all data generated by these devices is processed and analysed to incorporate applications that will make life easier for the end users. This article proposes that community members of a specific urban zone, prone to flooding, collaborate in sharing information about weather conditions using IoT techniques. The gathered information is sent to a cloudlet to be analysed together with information from weather forecast and a network of sensors and surveillance cameras installed in specific areas inside and surrounding the studied zone. Having members of the very community studied involved in the process will exploit the available IoT technologies and the use of crowdsourcing at a lower cost leading to the development of what is called Smart City. This paper revises the available technology and proposes a system that will help in collecting and evaluating information for prediction purposes as to whether the community involved is at risk of being flooded. It is being noted that this risk is getting higher every year due to overpopulation, bad urbanisation, and climate change. Results show that the use of this technology will improve weather forecast so the community could react in time in case of flooding threats.

Keywords: Crowdsourcing · Internet of things · Smart cities · Flooding risk · Resiliency

1 Introduction

Flooding risks in densely populated urban zones is becoming a big threat for its inhabitants; these cities are at danger not only for the material loses but for health hazards and even loss of lives. The problem arises principally from the lack of urban planning; it is possible that the urban services were initially designed for a number of houses and little by little were overpopulated leading to a disaster when the pluvial rain couldn’t get its course through the normal planned way. Another situation that worsens this condition is the waste thrown at the drainage that clots it. Anyway, this circumstance

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requires a preventive plan to give its residents enough time to react in case that flooding might occur. Thus, this paper reviews some already proposed systems and how they have helped distinct communities, in some cases information regarding flooding problems has been obtained through interviewing members of the affected communities. These investigations helped to identify communities' needs, concerns, and experiences about past flooding events, to finally propose a technology solution system to help attend these requirements. IoT and Crowdsourcing are techniques that support multiple data sources and are equipped with the latest technologies offering broader range of capabilities for enhanced connectivity, storage, real-time analytics, and cost-effective applications [1]. The system we are proposing consists in developing applications like flooding prediction and early warning system (EWS) with the help of incoming data from residents and data from surveillance cameras and sensors especially installed in specific points at the studied zone. These data will be helpful to predict the flooding phenomena. This is achieved by acquiring data in real time and being able to process it and present it in an easy way in order to support the residents in decision making in a fast manner.

Crowdsourcing is a concept where masses of the public get together to work in a specific task that otherwise would be done by employees or specialised persons. In our specific case the persons are members of the studied community that will help in reporting situations that they consider contribute to the flooding problem; reporting what they observe in their community and weather changes that will be of help to predict a possible flood event. This information is intended to be directed to the local authorities and, accordingly, they would have to attend the needs of the community. In this sense, utilising IoT leads to what is known as Smart City which constitutes a concentrated use of information and communications technologies (ICT) [2].

There are many projects that have integrated IoT with smart city environments such as the work of Zanella et al. [3], where a complete review of the architectures, protocols and technologies for a web-centred service based IoT structure for a smart city project is presented. In [4] a framework for the development of a smart city by implementing IoT is proposed. Here the authors emphasise the need for intelligent cities as it mentions that by 2050, 70% of the world's population will live in cities and surrounding areas. In their work Mitton et al. [5] combine Cloud and sensors to develop a smart city and define the concept Cloud of Things (CoT) as more than just interconnecting things. It provides services by abstracting, virtualising, and managing things according to the specified needs of the end users. Hence, new and heterogeneous things can be aggregated and abstracted enabling things as a service known as CoT.

2 Crowdsourcing and IoT

Crowdsourcing [6] is the process by which streams of data are collected by a large number of people. These data are sent to a server to be analysed using different types of models. This data analysis task turns out to be high time consuming, so big-data techniques need to be included resulting in a more robust modelling approach. According to [3] IoT is nowadays present in all ways of life where global connection and big data applications are enabling innovation all around the world. It is seen as a possible solution for many problems such as air pollution, transportation, weather changes, health monitoring, etc. There is also the fact that many people are living now in big cities, which means that the demand on services will increase exhibiting the reality that urban infrastructure is not meeting the needs of its citizens due to bad planning and overcrowding. Such needs can be and should be met using IoT technologies. Flooding prone cities would benefit from crowdsource flood reports combined with IoT and traditional detection data from forecast environmental monitoring stations as well as on site installed sensors. All these data could be of help in deciding whether a given community is at risk. According to Fenner et al. [7] crowdsourcing by itself has around 80% accuracy but combined with other techniques like weather forecast and in site sensing could reach an accuracy of 96%. From here, it is seen the importance of combining IoT and crowdsourcing; together will lead to an efficient preventive and warning method. In addition, as stated in [8, 9], smart cities depend on ICT solutions to improve our quality of life.

Today, daily used objects equipped with computing, storage and sensing abilities, enabled to communicate with other similar objects, can become part of an IoT system. In this case, citizens equipped with intelligent phones can generate data about environmental changes that both sensors in their smartphones and they themselves are seeing in their communities in real time. They can upload photos and text or voice messages to a collector. All this information together with the local weather forecast system could be analysed for mitigation and prediction purposes. A local network of surveillance cameras and sensors planned for a project like this is justified because the forecast environmental monitoring stations present high spatial and temporal variability inside urban areas. When sensors and cameras identify changes in the ambience, they could be compared to the other sources to identify if flooding is prone to occur. Sensors may be able, via an application, to request users nearby for more information such as description of ambience, images, videos, etc. This information together with weather forecast could help in evaluating and assessing if whether flooding is about to occur so citizens could decide what actions to take.

3 Technical Background

The applications required for this project will have to handle an enormous variety of data for the IoT system. Therefore, the need is for a communication infrastructure capable of unifying the heterogeneous technologies available to develop a smart city. This article presents a general reference background for the design of an urban IoT. IoT is the convergence of both sensing environments and the Cloud. The Cloud provides services by abstracting, virtualising, and managing things, its purpose is to implement services to provide indexing and querying methods applied to things such as sensors, actuators, computing, storage, and energy sources [10]. The huge amount of data and services that the Cloud must manage gives way to another concept: Edge Computing. Edge Computing attends the requirements of shorter response time, processing, bandwidth cost saving and data safety and privacy. Within Edge Computing there are basically three types: Fog computing, Mobile Edge Computing and Cloudlet computing.

Fog computing is an intermediate layer between edge and cloud that provides distributed computing, storage and networking services between end devices and cloud computing data centres [11]. Mobile Edge Computing (MEC) focuses on mobile clients within the radio access network (RAN), works with edge servers at the RAN base stations [12]. Cloudlet Computing [5] is an evolution of Mobile Cloud Computing (MCC) which are small resource rich data centres that can be positioned strategically in close proximity to end users, it mimics the cloud allowing for intense computing closer to the data source. The proposal is the development of a system that analyses data coming from multiple sources in real time that will assist in the inquiry on whether the urban zone in question is at risk of flooding.

In crowdsourcing, participation from the very own inhabitants is crucial as the users share information from IoT mobile devices [13]. Under this scheme, it is inevitable to congest the actual computing service called the Cloud, getting a drop in the quality of service (QoS) that in this case is of critical importance when flooding might occur. The solution for this matter is the use of Edge Computing where resources are positioned at the Edge of the Network, so these resources can handle computational demanding tasks, reducing latency. This information is sent to a collector by a gateway where it is examined together with information from official weather forecast, surveillance cameras, and a network of sensors installed in specific areas surrounding the studied zone. As this information must be accurate and in real time, it cannot rely on cloud systems, there is the need for a private system (cloudlet). Efforts to concrete edge computing have been significant in recent years giving birth to Fog computing [14], where a virtualised platform for networking ad computing services are distributed within the cloud to things continuum. Satya et al. [15] first defined cloudlet computing: a network of small data centres in a box (cloudlets) to act as an intermediate layer between user and cloud, this is a local processing unit used for temporary storage and processing.

The cloudlet evaluates the data coming from smartphones identifying spatiotemporal patterns; users can report weather changes such as temperature, humidity, and wind [16]. This information can be used by applications to infer to a certain degree of accuracy the severity of a possible rainfall. In this scenario, when there are enough data taken trough time it is possible to observe patterns that as well will be useful in flooding prediction. Once patterns are available, it is probable to model how weather changes lead to strong rainfall flooding and then direct alerts to citizens. In this case, social media plays a big role when there is the need of exploring people's experiences such as how they describe their impressions about weather changes [17]. Considerations like different types of characterisation of land use such as buildings, green areas, areas that used to be unoccupied and now have been paved for private use, commercialisation, both fixed and itinerant, use of land with bad disposal of material residues, etc., have to be taken into account for design purposes.

4 Architecture

Architecture has been defined [18] as a set of functions, states, and objects together with their structure, composition and spatial-temporal distribution. The development of a smart city is usually based around a centralised architecture, where it must have the ability to work with a heterogeneous type of devices which generate different types of data. These data are sent via ICT to a control centre where will be stored, processed, and retrieved according to the needs of the end user. Hence, the integration of different technologies is the main feature enabling this architecture to evolve if required, to allow for other devices to be connected to support new applications and services. In the development of this project the actual technology of the urban zone in question needs to be addressed, to make possible the monitoring and control for the weather prediction. Therefore, new IoT technology needs to be installed. Setting up this technology represents a huge challenge due to the considerable number of heterogeneous devices. Correspondingly, to be considered in this project is the IoT infrastructure maintenance to keep up with Smart Cities. Citizen participation sums up to IoT infrastructures by applications on their smartphones generating vast amounts of data. For these records, data models need to be created considering semantic descriptions of the urban atmosphere. This project proposes a platform to facilitate the services to the community members. In smart cities is important to adjust citizen's data streams to a data model that would facilitate its usage. The logic used will depend on the background of each community, as the model must take into consideration social, economic and idiosyncrasy to create new rules to integrate the community organisation into a decision model. Also, these data would be accessible to local authorities, making them aware of the situation in real time. Using these information/data the authorities could implement or improve the appropriate actions to control/prevent the flooding risk in the community.

Lots of issues need to be attended during the system designing, such as: how citizens can have easy access to the generated data, coming from heterogeneous sources? Is the proposed infrastructure robust enough for the collection of data from community members? How to use information coming from installed sensors and surveillance cameras? The proposed platform implements a directory that contains all data sources generated within the IoT infrastructures, from crowdsourcing data streams, data generated from the network of sensors and surveillance cameras. These data in time could also be of help when needed for statistical purposes as to detect whether climate change is worsening the flooding problem. To construct a model for weather prediction as in our case, variables such as temperature, wind, air pressure etc., must be established from theory like physical equations and from the empirical experience. These models are based on everyday language concepts. The relationship between different concepts should be automatically detected by a machine learning algorithm. This paper proposes the following architecture to show how an application would perform in analysing weather conditions for flooding prediction. The order is as follows: crowdsourcing and sensors, data transmission, data collection, data processing, and application.

Crowdsourcing and Sensors. This layer consists of three types of data sources: smartphones, sensors and surveillance cameras. The users also can send voice or text messages as well as photos. The members of the community can send information daily or whenever they detect the environment is changing like air, wind, humidity etc. Additionally, they can co-operate giving information when they see situations like for example when they see that litter is clotting the drainage, or any other situation they consider might worsen flooding.

Transmission of Data. All data coming from members of the community, sensors and surveillance cameras should be sent to a server for processing and analysing. At this point, forwarding and routing protocols must be well defined in advance as the nature of the heterogeneous data calls for enhanced nodes able to perform fine.

Data Collection. Data is collected from selected nodes that can preserve privacy for all data contributors. This layer depends on both computing and human interaction, so its function has more weight over the other three layers.

Data Processing. At this point what really is important is the fact that it is possible to singularise frequent data patterns that will be useful when it comes to compare how climate change is affecting or not the studied community. To solve this problem, a method is developed to transform the raw data that would allow clearly identifying patterns and measuring them.

Application. The function of this layer is multiple, such as data management, user interface, etc. It generates services for the crowd, so they can see results in a manner easily understood for them. A user interface is generated to enable communication between machines and humans. There should be an application that combines human interaction and electronic mechanisms. This layer has the task of integrating data streams with other events from lower layers to be stored in a common data storehouse.

5 Technological Requirements for the Community

People need to have access to an early warning system (EWS) in order to mitigate flood risk within communities including an evacuation or emergency plan. This EWS will help in taking measures of adaptation, preventive and reactive procedures by collaborating with neighbours and local authorities to build resilience. For the preventive plan, the community participation in detecting possible situations that worsens floods is of importance as well as acting upon it for alleviation purposes. Nowadays, many people are familiarised with the use of technology (being social media or web pages) to report or receive information they consider important about the issues that affect their community. Therefore, it would be interesting and important to take advantage of this matter by implementing a web page with an easy access and understanding of the information. This might be quite substantial to present it in a graphical way, so people that is not very technical can be informed in time when an event has a high probability to happen giving them as much time as possible to act appropriately. According to Alexander et al. [19], resilience includes the capacity to resist, to absorb and recover, and to adapt. Based on the work of Mees et al. [20] where the authors present an analysis on flooding in 5 different European countries, each country present different levels of flooding risk, and for all of them most of the responsibility in finding solutions depend on the state. Thus, being aware of this, in their work they start to consider the participation of citizens together with the authorities for a better understanding of the problem and ways of solving it. To accomplish this goal, they present an analysis of coproducing flood risk management through citizen involvement. They gathered information mainly from citizens, although analyse government documents as well. By analysing both kind of information, enhancement of the whole data was attained.

From the conclusions presented in [20], on every country studied there were stated that coproduction was an important issue about flood risk and for a suitable management of the problem. They developed coproduced practices on Flood Mitigation and Flood Preparation. As for mitigation in England, they analysed flood highs on the floodplain, took measures for property level protection (PLP) across the country. As for Belgium they developed a project on flood-resilient building and PLP only in exceptional cases. In France there were limited PLP and implemented local programs for some buildings. Netherlands increased water retention in neighbourhoods, also had plot projects on flood-proof houses. Finally, Poland rarely have flood protection at property level. For the same countries, in respect to coproduction in flood preparation, England generates community flood action groups with voluntary schemes, as well as national and local awareness raising campaigns. Belgium presents only in very few cities voluntary emergency teams. In France local authorities are obliged to give information about risk and how to behave on an event by volunteers and civil servants. As for the Netherlands they have campaigns of awareness through volunteers and professional fire services. Finally, Poland works through local citizen initiatives with voluntary fire brigades along with professional fire services.

It is increasingly argued that a diversification, coordination and alignment of Flood Risk Management Strategies (FRMSs), including flood risk prevention through proactive spatial planning, flood defence, flood risk mitigation, flood preparation and flood recovery, will make urban agglomerations more resilient to flood risks [22].

In their paper, Mees et al. [20] conclude that co-participation of citizens in resolving the problem of flooding is important for resilient purposes. Also, they state that it really does not matter what country is under study and the differences in which they tackle flooding, the problematic is much alike and the main stages to deal with it are quite similar such as: mitigation, preparedness before and during the event, and continued work after the event. Therefore, for the project proposed in this article it is possible to adapt these data to some areas of Mexico, particularly in Mexico City where there are many communities prone to flooding. Accordingly, we have proposed in the following table the different stages and possible technology aids to the cocreation of smart cities. Later on, it is expected to corroborate this study in a small community within Mexico City, where it is expected to research the perception and adaptation of the communities to climate change-related risks, and in particular to understand people's perceptions and experiences on flooding events towards determining specific needs to mitigate such events. From the literature review and in order to adapt the technology to the community needs, it is observed that some of these needs are solved only with information supply, others with the combination of sensors, processing and communication technologies. Regarding to the use of technology, for a better management of a flood event, four stages have been identified: Mitigation, Before, During, and After flood. Hence, we propose technology requirements to attend each identified need in each stage of flood management. An example of these is described in Table 1.

An EWS needs data analysis, prediction models, and sensor fusion to forecast possible flood events based on data supplied by sensors and people. From the analysis in the literature of flooding events the technological aids requirements can be divided into three levels (see Fig. 1):

First Level Technology Aids (Informative). This consists of storage and communications technology to concentrate and supply information, about local reaction plans in a flood event, for example, to the community inhabitants, namely, a platform like a web page and/or a mobile application.

Table 1. Matching of needs and technology requirements for flood events management.

Stage	Aspect	Need	Possible technology aids
Mitigation	Infrastructure maintenance and adaptation	Insufficient drainage	Sensor Technology for monitoring the amount of rain Processing Technology to analyse the data in a rainy season to evaluate the current drainage system Communications Technology to report the results
Before	Information for risk management for inhabitants	Reduce damage to homes	Communications Technology to send information to inhabitants about what they must do before, during and after suffering a flood
During		Vehicular mobility problems to get to their houses	Sensor Technology for monitoring avenues and/or streets Processing Technology to analyse the sensors information Communications Technology to present safe streets in a map
After	Health risks	To know about the health problems that the community faces after a flood and the stagnation of water. (Moreover, if they are sewage)	Communications Technology to issue prevention recommendations for health (cleaning, etc.)

Second Level Technology Aids (Monitoring). Monitoring and situational awareness information on flood events in real-time. This can include the installation of sensors and crowdsourcing data from community inhabitants by means of text messages, social networks or from mobile apps; dashboard integrated with maps for real-time visualisation of information and registry of historical data and trends.

Third Level Technology Aids (Analytics). Analytics of the captured data, prediction models, and sensor fusion algorithms to forecast future flood events, generate automated alerts, notifications, and data sharing.

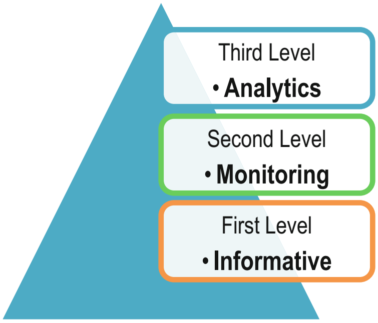

Fig. 1. Levels of technology aids for flood management.

The overall smart technology intervention will allow to go from a reactive to a proactive response to flooding events and ultimately to a predictive flood management. Furthermore, the overall aim of any technology aid is to increase community's resilience to flooding. IoT based smart cities depend on ICT, so the study of the main communication protocols is a must. IoT uses many short and wide range communication protocols with the purpose of transporting data between devices and servers. ZigBee, Bluetooth, Wi-Fi, WiMAX and IEEE 802.11p are the most used short-range wireless technologies. Within wide range technologies are Global System for Mobile Communication (GSM), General Packet Radio Service (GPRS), Long Term Evolution (LTE), Third Generation Partnership Project (3GPP). There is also Low Power Wide Area Network (LPWAN) technology which is a promising solution for long range and low power IoT and machine to machine (M2M) communication applications. The major proprietary and standards-based LPWAN technology solutions available in the market include Sigfox, LoRaWAN, Narrowband IoT (NB-IoT), and long-term evolution (LTE)-M, among others. For the development of this project the LoRaWAN, Wi-Fi and GPRS communications protocols are proposed to be explored for the monitoring of flooding prone areas.

6 Related Issues

Another big problem is the fact that people need to have an incentive to participate, be economical or social. In this case a social benefit is the key. Community members need to know that they are part of the solution, highlighting this is the biggest incentive in overpopulated urban zones attracting and encouraging more involvement. An additional challenge is how to send data from members of the community to the server/cloud because these data can be text messages, voice or images. Accordingly, for example, in the case of text or voice messages, there is the need for analysis that depends a lot on language, culture or semantics. Also, characteristics of the server's devices must be considered, such as bandwidth, wireless communications, frequency of data sending from users, etc., all these problems should be addressed with data management and data processing. Data redundancy is another important issue as most of the time there are data coming from multiple sources such as sensors systems, or multiple members of the community which causes what is called data redundancy. In this case, it is of importance to have a selection data system able to estimate the best approach. Especially when there is also the semantics problem involved, this represents a more intricate issue. Therefore, detection technology must be developed to guaranty the quality of the data. The proposed IoT architecture is the simplified three layers IoT model presented in Fig. 2.

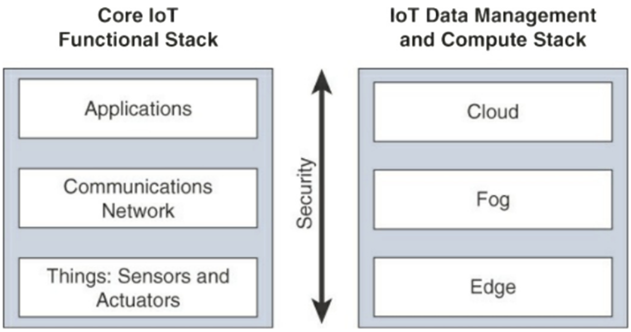

Fig. 2. Simplified three layers IoT architecture (adapted from [21]).

At the bottom layer are the sensors (and, if needed, actuators) nodes, which are proposed to be located at points in the studied zone where certain amount of rain flow comes into the zone, as for example, communities located at valleys which are surrounded by hills where it has been detected that in a matter of seconds huge amount of water may come into de urban zone. Therefore, a set of sensors could be used to measure rainfall, e.g. rain gauge sensors and/or water level measurement sensor (radar or ultrasonic sensors) are proposed to be installed at specific locations at these points at street level. Another set of sensors could be installed at street lights in the surrounding area of study with the purpose of sensing the level of rain fall on such streets so the locals could know if it is safe to walk or drive through theses streets. Finally, and most importantly are the sensors that could be installed at street level in the actual community to detect the amount of rainfall that will lead to the decision on whether the community is at risk of flooding. Also, considering at this layer is the information gathered through smartphones and surveillance cameras.

The communications and network layer will collect measurements from sensors nodes, send these data together with the information from smartphones and cameras to gateways which then will send all collected data to the cloud (or to a private server) via Internet where these can be analysed, or alternatively edge computing technology can be used to perform data analytics closer to where the data are collected. The cloud has three basic types of services to offer: as infrastructure for storage of data, as platform for computing and as software for delivering IoT services.

At the application layer services can be provided such as data processing for analysing the data fetched from the devices (sensors, social networks, cameras, etc.) and transforming these into usable information, for example prediction of flooding, alarm activation if thresholds are surpassed or statistical analysis and trending. Also, graphical user interfaces (GUI) can be provided for users, for example to use smartphones to provide users access to data or to other IoT applications. In addition, clouds can be used to analyse, sort out and store the data, and websites can be used as interfaces.

For the processing and management of data, a pre-processing and event detection must be performed in advance to convert it into knowledge. For this task it is essential to implement algorithms such as genetic algorithm or neural networks. As for data interpretation it is important to present to the end users' information that is easily understood. In this case visualisation is important for the residents so they can take decisions on whether flood is prone to occur. Visualisation for this project is expected to be through a web page where residents will have easy access by their phones or computers. It is proposed that data is going to be visualised using geo-spatial maps for a more friendly presentation for the end user being keyword based, semantic based and quality based.

7 Proposed Technologies

At the first level a website is proposed and/or a mobile application to concentrate and make available diverse flood management relevant information. This information should be shown in a friendly form, especially for those citizens that have little knowledge of digital technologies. The proposed informative webpage could present sections as Memory Reinforcement to show past events, actions taken and which of them worked and/or failed; Risk Management to inhabitants; Days of waste collection information, Vulnerable areas map, Institutions information and a Health Risk consequences guideline. In Fig. 3 a proposed web page for informative needs about flooding events is shown.

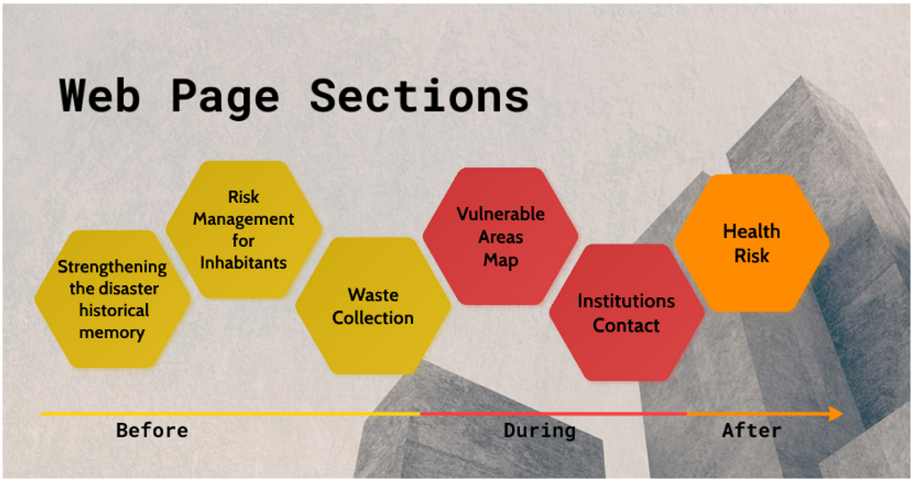

Fig. 3. Informative web page.

The second level considers monitoring and visualisation for situational awareness of flood events in real-time, which includes the installation of sensors and the use of communications technology using the three layers IoT architecture and crowdsourcing technology. Therefore, the first proposal to attend this need level is to integrate a minimum sensors kit by a block (street) to be monitored, which is scalable and modular; hence, can be scaled up to a suburb, town or even a city. Also, at this level a dashboard will be integrated with maps for real-time visualisation of information and registry of historical data and trends. This technology proposal is described as follows:

By Block:

- HD (High Definition) outdoor camera (powered with solar panel).

A camera designed to withstand rain, snow, and extreme temperatures, typically connected to a Wi-Fi network, which allow to view live video of the activities occurring outside. HD is defined by specific resolutions at specific frame rates with a specific aspect ratio. HD refers to cameras with a standardised resolution of 720p or 1080p (horizontal). This sensor could help in monitoring the streets and strainers.

- Water level sensor (radar or ultrasonic) for level monitoring in regulating streets. A water level sensor is a device that is designed to monitor, maintain, and measure liquid (and sometimes solid) levels. Once the liquid level is detected, the sensor converts the perceived data into an electric signal. This sensor could help to monitor the water level on the streets.
- Smartphones for data collection. This device could help to send images and/or videos, texts and even voice messages.

By Suburb:

- Disdrometer and / or weather station with rain gauge (powered with solar panel).

A disdrometer or rain spectrometer is a laser instrument that measures the drop size distribution falling hydrometeors. Based on the principle of optical laser active detection, the disdrometer can continuously observe the raindrops definition size,

Fig. 4. OTT Persival2 laser disdrometer (https://www.ott.com/products/meteorological-sensors-26/ott-parsivel2-laser-weather-sensor-2392/).

velocity, and quantity of raindrops. This device could help to monitoring the amount of precipitation and help to predict the trends in rain fall. Figure 4 shows an OTT Persival[2] laser disdrometer.

A weather station is a facility with instruments and equipment for measuring atmospheric conditions to provide information for weather forecasts and to study the weather and climate. The measurements taken include temperature, atmospheric pressure, humidity, wind speed, wind direction, and the amount of liquid precipitation (rainfall).

Finally, the third level oversees the analytics. The data signals will be processed, therefore depend on the results, to send messages to inhabitants and/or institutions (using ICT). Besides, warning or announcements can be sent through a website and/or mobile applications. The processing could be done on the edge or in the cloud. Also, a deeper analysis could include neural networks to predict a hazard.

8 Conclusion

Building smart cities calls for the participation of its citizens defining strategies that involves them, getting their participation in discussions and proposals for the development of technologies that help them with the actual issues that affect the whole community. Implementation of IoT technologies in urban zones will enable the development of the concept of smart city, giving rise to a system able to help in dealing with the problematic that overpopulated urban zones generate by applying multidisciplinary strategies. By involving the residents in the problem-solving leads to the co-creation of a more resilient community implementing state of the art technological tools to communicate, monitor and mitigate flooding risk in vulnerable population. We have presented a system able to analyse heterogeneous data coming from crowdsourcing, surveillance cameras and a local network of sensors for an overpopulated urban zone. Many urban zones in Mexico suffer from severe flooding every year; this flooding may be the result of bad urban planning and climate change. The resulting information gather from these three sources is going to be used for statistical analysis to determine the probabilities of flooding in the studied zone. In this work a text analysis is proposed to be used to obtain information on ambience changes. Reported events will be computed by sampling different text messages which have been organised on type of event by determining a set of keywords indicating the weather state. The system we propose can be adapted for several applications to enhance community life (such as air pollution monitoring, health care, transport systems, etc.) as well as been adapted for other similar communities. Additionally, the development of this project highlights several challenges areas and research opportunities within communities. Investigation should be addressed on models and design patterns for crowdsensing systems using multidisciplinary sources of knowledge which should include social science, computing, sensor systems, community members etc.

9 Future Work

This project will enable the implementation in the short time of a crowdsourcing and IoT system to collect, communicate, store, process and visualise data and information that is going to mitigate flooding risk, towards creating resilient communities facing these events. At the time of writing this paper, we already have identified some communities that present flooding problems in Mexico City and for mitigation purposes the project is in the stage of technology identification, purchase, and integration of the overall system. This will enable future research and experimentation with smart city solutions as cities will, in time, depend more on technology to provide facilities to support solution to other worrying issues such as transportation, energy usage, waste management, health care, mobility, etc., in ever increasing overpopulated urban zones.

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