Towards Smart-City Implementation for Crisis Management in Fast-Growing and Unplanned Cities: The Colombian Scenario

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Abstract

Natural or human-made disasters could do huge damage in urban areas and eventually could take lives. It is fundamental to get knowledge of the event's characteristics to dispose of hasty information to help affected people or to prevent all the citizens from the danger zone, and then it will get time to respond to the crisis. Internet of Things (IoT) has a big impact on this kind of situation because a large amount of data through different devices could provide information about the situation, and about the people that are involved in the crisis. In a disaster, one

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of the big problems adding to the principal crisis is the disinformation,
for that reason is necessary to have available and trusty data in case of
disaster, also to know the data that provided the information system. To
inform the affected people around the crisis event, there is exist some
previous works that have used data from sensors, social networks text,
or images, to finally be processed [1],[2],[3],[4],[5],[6],[7],[8]. This paper
aims to review study-cases where cities implement crisis management
platforms, focus on IoT environment where applications use hybrid data
to be processed to help citizens in a crisis situation.

Keywords: Crisis management; crowdsensing; unplanned cities;
smart-cities; internet of things.

Construyendo una ciudad inteligente para la gestión de crisis en ciudades de rápido crecimiento y no planeadas: escenario en Colombia

Resumen

Los desastres naturales o provocados por el hombre podrían causar
grandes daños en las áreas urbanas y eventualmente podrían cobrar
vidas. Es fundamental conocer las características del evento para disponer
de rápida respuesta para ayudar a las personas afectadas o para evitar
que todos los ciudadanos salgan de la zona de peligro, y luego se
tendrá tiempo de responder a la crisis. El internet de las cosas (IoT)
tiene un gran impacto en este tipo de situaciones porque con una gran
cantidad de datos a través de diferentes dispositivos podrían brindar
información suficiente sobre la situación y sobre las personas involucradas
en medio de la crisis. En un desastre, uno de los grandes problemas es
la desinformación, por eso es necesario tener datos confiables en caso
de desastre, y disponer de una infraestructura capáz de responder en
un estado de emergencia. Para informar a las personas afectadas sobre
el evento de crisis, existen algunos trabajos previos que han utilizado
datos de sensores, texto de redes sociales o imágenes, para finalmente ser
procesados [1],[2],[3],[4],[5],[6],[7],[8]. Este documento tiene como objetivo
revisar los casos de estudio donde las ciudades implementan plataformas
de gestión de crisis, y se centra en el entorno de IoT donde las aplicaciones
utilizan datos híbridos para ser procesados y ayudar a los ciudadanos en
una situación de crisis.

Palabras clave: Gestión de crisis; administración de los datos; ciudades
no planeadas; ciudades inteligentes; internet de las cosas.

Introduction

Looking towards an Smart-city implementation to achieve on fast-growing and unplanned cities where data, user interaction and Internet of Things (IoT) infrastructure is limited. This paper aims to gather research where applications are used to alert citizen in the middle of the crisis and the requirements for the implementation are minima for a complete smart-city employment. One of the most recognized references in IoT projects is the University of Padova/Italy [9],[10] where they implemented different applications, infrastructures, and networks to create a smart city project into the university, where researches can make test and IoT-Lab in France [11]. In addition to that, single projects are focus on applications for the benefit of the citizens as alert o mitigating disaster applications,these projects are references as tools of implementations for a smart-city. Huang *et al* [12] propose a system for flood control in Quanzhou-China, where presents a system architecture implemented, a functional framework, and the design of the decision support sub-system where analyzes the database from hydraulic, hydrologic, and social-economic data.

The architecture shows what variables intervene to make decisions and inform the citizens. At the University of Virginia [13] Webber et al developed an app to get information across crowdsourcing, but also proposes a method of trust determined by Machine Learning. Koontanakulvong *et al* [14] analyze the lessons learned from floods in Bangkok in 2011, and related how the study in the university helps to the people look for a place safe determining the elevation of the water in the city. In Texas was implemented a framework to identify trends in tweeter looking for sensing the emotion of people about some crisis situation [15], this is important for determinate fake news or also tracking the emotion of a certain country in tweets. This work test different situations like the trends in Boston for arts and entertainment or the trends in Dallas for shops. Kantarci et al [7], propose a Framework where IoT can enhance public safety by crowd management via sensing services that provided smartphones called it Trustworthy Sensing for Crowd Management (TSCM).

Wang *et al* [1] compare crowd-sourcing data and social media data
existing to generate processed information to avoid crisis event, o to
inform citizens about safe zones, as these researches related:

- (2011) Haiti earthquake: They analyze Twitter and Facebook
  information.

- (2013) Sensing by Flicker images for floods maps.

- (2015) Explores to use of Twitter data for early detection of
  floods.

- (2015) Weather depth information for Twitter's photos.

- (2016) Floods in Indonesia with Twitter data.

Sudrich *et al* [2] get Crowdsourcing data as: Social media and
sensors information, calls, events, all this data will be processed
to gather result of alert comparing anomaly detection for Urban
data. Zheng *et al* [6], according to the previous research about
ontology, merges some data for different sourcing (Ubiquitous) and
diagnosing one result. The data analyzed is the noises from different
sources (Natural language, numeric data) and generates a result
where shows the levels of noise in New York. Ragini *et al* [5]
analyzes big data analytics for disaster response and recovery through
sentiment analysis. He notes that social networks are increasingly
used for emergency communications and help related requests during
the disaster. Proposes a methodology to visualize and analyze the
sentiments on the various basic needs of the people affected by the
disaster. Proposes a categorization and the classification of social
media ensures an effective disaster response and recovery. Kim *et al* [8]
evaluates the characteristics in social networks between the disaster
in the case study in a flood in Lousiana (2016). The representation of
social networks although network graphs to see the connections (Likes,
Shares, Fav's, etc), showing the interaction between social networks.

Some countries social network has become an important source of information and miss-information, day by day the use of them and the data related with are increasing [16], there are more chances to get information in emergencies through it. Xu *et al* [3] work analyze some use-cases before where social network data could be used to inform the citizens and tracking a crisis event in the city. Marek *et al* [17] work is the narrative of how a new smart city is building after an earthquake in New Zealand. Ding *et al* [18] propose a social and crowdsourcing factorization machine where evaluates the influence value between users in some social networks, like food and movie opinions. These works show architectures review that works for a smart city on fast-growing and unplanning cities. Two recent research shows an architecture implemented with similar case-studies for crisis management. Gaire *et al* [19], implement an architecture for crisis management in Australia, other similar implementation in Brazil for De Assis *et al* [20], show a summary of approaches and main functionalities, where proposes a software solution where compares and analyzes the information of each case-study suggesting new infrastructures for smart-city which it will work for crisis management in cities where requirements are minima, as the case study of the city Bucaramanga/Colombia and to extrapolate solution to cities with similar characteristics as highly dense and unplanned cities. This paper aims to review different IoT implementation for crisis management projects, where similar cities characteristics can give solution to specific needs from the citizens.

In terms of middleware architecture, a case-study in Brazil[20] and a similar one on Australia [19], it uses an architecture similar to Lambda [1] where sensors and processing devices works for real-time and business intelligence processing. These works propose a middleware layer where has data management split into two parts, Stream Management and, Batch management, with large amount of data provided by diverse sensors. According with the needs of the project real-time information must be processed. These papers also suggest some tools for use in the development of the middleware.


[1]https://lambda-architecture.net/

That Architecture could be implemented in generic projects, but some
unplanned cities have not the same devices or geographic connections,
but architecture can be implemented to focus on real-time and
business intelligence processed.

1   Fast-growing and unplanned cities weakness

The Crisis-scenario in Colombia depends on the particularity of each
city, some of them are building between mountains having disasters
related with landslides and floods. In July of 2019, an emergency
occurred in San Gil, a small town city in Colombia [21]. This kind
of disaster could be prevented o to alert people near to the crisis
area but it depends of the hardware, software, network and data.
The World Resources Institute [2], have disposal the Annual Expected
Urban Damage by Country, This tool shows the affected population
estimates the annualized number of people affected by inland flooding
in any given area. The analyzer overlays a global inundation map on
a global population map to estimate the total population exposed to
inland floods, nevertheless it is not enough for data to be processed. In
other cities from Colombia to exists other frequent problems related
with strikes, common robbery or, crossfire conflicts in other critical
areas, for example in Bucaramanga/Colombia still exists homicides
in certain zones of the city [22] (see Figure 1). With the knowledge
of the common critics' problems and the areas where it is possible
to prevent or to help people for a sudden disaster but, it demands
data help citizens in a crisis situation, as part of the implementation
of a smart city, next chapter shows in the case scenario of a city in
Colombia, the available data, and how this can be used related to
related researches.

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[2]https://ww.floods.wri.org/
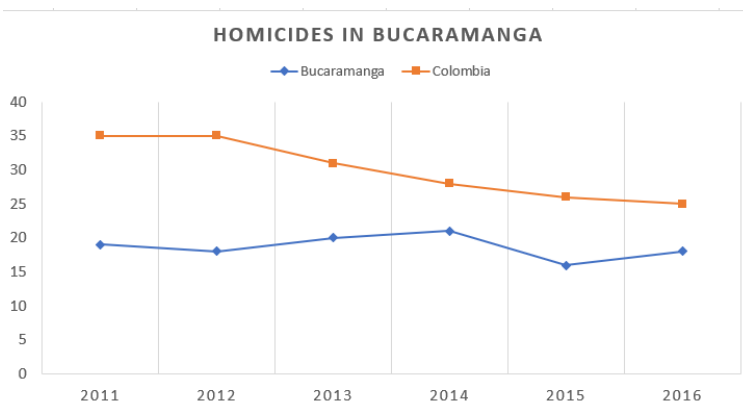
**Figura 1:** Homicides in Bucaramanga 2011 to 2016 [22]

1.1 Data available

This work proposes to evaluate an example of growing-fast and unplanned cities as Bucaramanga/Colombia. As part of a smart-city implementation, infrastructure, network, applications. The accurate data helps to be processed to make decisions in a crisis emergency. In unplanned cities data can be reached distributed and isolated. In this scenario the data available are cameras installed in some critical spots of the city, weather sensors, and social networks. From video recording can be processing using deep learning software obtaining quantities of each vehicle and pedestrian in the street, with a micro-simulation model created and the conclusion of the work was a new speed bump traffic installed in a track of the street making reducing pedestrians accidents (see Figure 2) [23]. This project is looking for enhance citizenship in the city by recording the behavior of the pedestrians and drivers [24], In addition to that, there are available pollution sensors, but data is private until 2020 [25]. The minister of technology and communications in Colombia (MinTIC[3]), creates a platform for share different kind of data available for research proposals called *Datos Abiertos*[4]. Lastly, meteorology data is available through The

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[3]https://www.mintic.gov.co/
[4]https://www.datos.gov.co

Institute of Hydrology, meteorology and ambient studies (IDEAM[5]),
the IDEAM has sensors with data available from internet platform
(Hydra), this data are historical and not real-time, the data it is
updated each 1', 30 or 60 minutes, depending of the sensor station.
For example, in the station Neomundo in Bucaramanga (see Figure 3),
have available temperature information, precipitation, wind's velocity,
and the data is updated each 2 and 60 minutes.
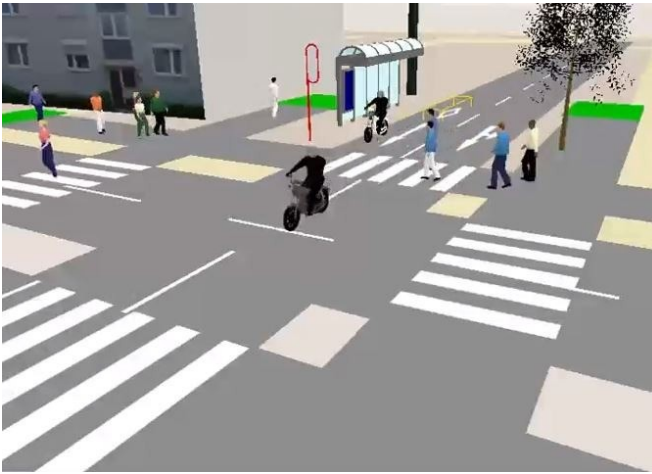
Figura 2: Micro-simulation of pedestrian behavior in Bucaramanga

Finally, access to social network data is available and useful
for a crisis alert application, because crowd-sensing is a good
source of a large amount of data due to the people that could be
near the disaster [26], nevertheless, the miss-information is highly
available. Thus uses images from social network is a way to prevent
miss-information [27].

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[5]https://www.ideam.gov.co
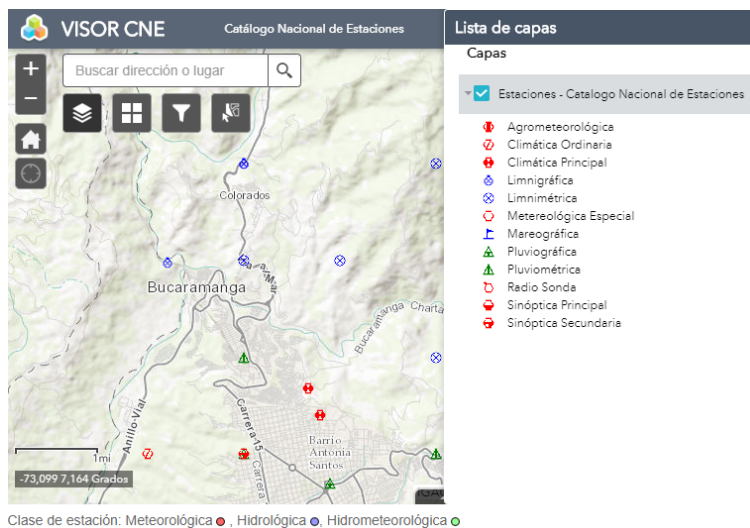
Figura 3: IDEAM stations' map

2 Requirements for a crisis management in grow fast and unplanned city

This paper explores previous applications that mitigate consequences in a city crisis where people's safety is risky. This study explores different architectures and tools available (applications and sensors) to unplanned cities as Bucaramanga/Colombia. This study review minimum requirements as data, infrastructure, applications, and user interactions. About infrastructure, architecture is part of the IoT topics where the implementation works for data streaming, processing, and storage. Two architectures and implementation of smart city service [19],[20], shows the heterogeneous data, and the necessity to be processing streaming and longer processing, in this way computing paradigm is also part of the research, Cloud computing for a large amount of data and permanent storage, and distributed processing with temporal storage, where is near to the users reducing latency of data [28]. The cloud layer could have Cloud data centers which are large pools of highly accessible virtualized

resources [29], but cloud computing is centralized and in a crisis
situation a distributed deployment could have a quick and stable
response, then we can establish the minimum requirements for a
smart-city with related characteristics (see Figure 4). In addition to
that, an architecture is necessary to implement into the fog computing
strategy, where there it needs streaming processing for sensors and
short-time data collection, thus it could be implemented the Lambda
or kappa[6] architecture.
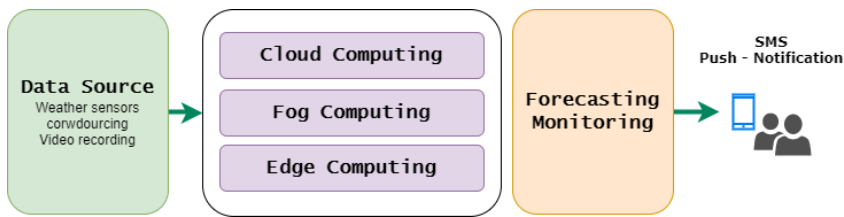
Figura 4: Requirements for a crisis management in grow fast and unplanned city

2.1   Edge computing Paradigm

Edge computing paradigm it exists in the proposed architecture, to
do not have a dependency of one source of data, for example, an
autonomous car it is necessary to have immediate information in
case a near collision, nevertheless, some projects with edge computing
paradigm have not a dependency on the cloud. Edge computer is near
to the user, this is frequently to use it in IoT to get different paths of
communications, in the way to have alternatives in a disaster situation
and low latency in the data transfer, but, also means less processing
capacity [30]. This architecture suggests computation near to the users
to keep processing information and use this computation to send alerts
to the nearest users, this paradigm could be implemented in the way
to get data available at no centralized part [31]. The cameras project
where the centralized part is from video, the audio could be quickly
processed with low-cost processor and near to the devices.

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[6]http://milinda.pathirage.org/kappa-architecture.com/

2.2 Fog computing Paradigm

Fog computing paradigm usually uses one or more collaborative end-users or near-devices to perform storage, communication, control, configuration, measurement, and management functions[32]. In this proposed architecture, the Fog computing layer has the task of use processing near to the users, but better processors and few nodes. In this case, it could have pre-processing of the information and also get other paths of communication between edge computing nodes in the case when internet connections fail [33]. In order to have temporary storage and high demanding applications as weather sensors, fog nodes could be implemented and geographically distributed reducing latency between sensors and cloud.

2.3 Triggers

Normally, to identify unusual data depends on the criteria of experts, people who know about the relation of the data and the relation with the interpretation. Then they can do or explain when the data is irregular, for example, if the pollution is highest of the average, or if have a specific boundary. For IoT and a large amount of data, it is possible to use artificial intelligence for known the irregularity of the data. This unusual data will be a trigger to alert citizens. Nevertheless, this just can be a suggestion, because a false alert, could be to generate panic in the city. With a large amount of data also is necessary an interpretation of the data when exists different sources of data, that's means accommodate different kinds of data sources, to join or understand the information behind that the ontology to understand the kind of data to get an alert. Nadal et al [34], provide a method that handles schema evolution on the sources, according to their industry applicability study. Also, introduce a structured ontology based on a vocabulary that allows to model and integrates evolving data from multiple providers. Before understanding the meaning of each data in one group, it decides to analyze the data separately. Sentences (natural language), images, videos, numeric

information. later would understand the information together. This
analysis includes the information available until at the moment.

2.3.1   Images Some research has proven that it is useful to analyze
images that aim to get information with social media unlabeled or
with natural language associated [1],[5],[20],[35]. certain developments
are their own as a proposal to get information to the images.
Nevertheless, nowadays exist different tools to analyze images, for
example, a pre-trained model for Machine Learning to recognize
elements in an image and tag it. Those services of artificial intelligence
is not necessary to train a model.

2.3.2   Natural language Natural language analysis highlights are
to understand the emotions, directions and understand crow-sourcing
with social network information. Some previous work analyzes this
information from different amounts of users used in crisis management
[1],[5],[15],[36],[37]. Although those research propose new frameworks
to manage this information of the works, and there exists different
SDK service to analyze natural language, where is a pre-trained
model which can detect emotions in the thread of a phrase, and also
important to detect addresses and descriptions of the situation where
the crisis are. In this specific case study, the information is in Spanish,
then is necessary to know that it is possible to lose information in the
translation or analysis of the words in the phrase.

2.3.3   Time series For time series triggers, the city has weather
data, sensors of air temperature, humidity, precipitation, atmospheric
pressure, and wind velocity in platform of IDEAM Hydra. It is
necessary to evaluate the information of each measure in normal
conditions, to do the comparison with the maximum critical levels
allowed. This is the first alert in the face of the crisis in weather
situations. In the case of the platform of IDEAM Hydra, already it has
a section with the high levels allowed by each measure, nevertheless,
in this project for the capacity of the test city, it is not possible to have
a connection directly with the sensor, for that reason in circumstance

of the internet connection failure, the architecture selected will be forecast using the last information received. In this aim, different libraries or companies are bet for a good tool to predict data behavior [38], for some examples, it developed a time series prediction with SARIMA and PROPHET with real data from precipitation in Bucaramanga city, adjusting the model which will work in an edge node, this work was presented as adjacent research (see Figure 5) [39]. This figure shows an information of raining historical data from a sensor of Bucaramanga/Colombia near to an airport. The set of data represents the monthly accumulated precipitation as a sum of the daily accumulated precipitation, in liters per square meter, from 2005-04 to 2019-03. In Figure 5 the raining historical data it is represented in blue color, and in orange the prediction made, for the confidence interval in the color grey, the axis x represents the dates where the data were collected, and the axis y represents the number of liters per square meter (mm). Analyzing the axis, the prediction adjusts the maximum to the wet season and the minimum to the dry season, which is an indicator that the SARIMA model can simulate and predict the differences between seasons. Another key indicator is that the original values are inside the confidence interval and finally it was also checked that the residuals plots followed a white noise distribution.
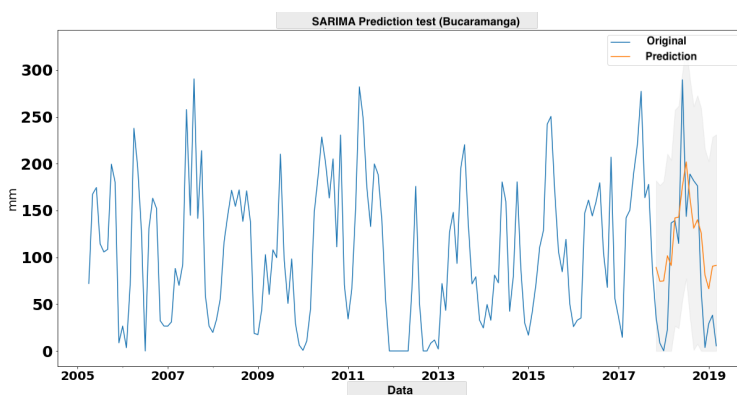
Figura 5: Time series prediction with real data from some sensors in Bucaramanga-Colombia

3   Insights

The review of this work shows significant applications where the implementation in a city can save lives or mitigate the damage for human-made or natural disasters. Despite applications, must be a different orchestration of technology behind, data and infrastructure. In the case-study in Colombia, an unplanned city, the data could be private, isolated, or distributed. The necessity of political decision will improve the basis of a Smart-city implementation where each part of the city and each possible situation could be managed. Regarding infrastructure, is not less than data, the network, and geolocalization of hardware and devices must work collectively. This paper explores the architectures' proposals wherein the implementation of different paradigms as fog and edge computing could enhance the processing and storage of the data.

4   Conclusions

This paper review some applications that could be used in the building of a smart-city implementation. The city chosen as an example is established as growing fast and unplanned because the data usage is not interconnected, informal, distributed, and in some cases private, and the technology works as individuals. This review shows some trending architecture and paradigms ready to be used in a smart-city implementation with the characteristics of the city.

Further work

The first part of the implementation of smart-city must be the integration of the technology already exists. Meanwhile, the applications could work separately in the advance as the social media data to inform people, other sensors and data must be centralized physically and legally.

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