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# Technological Advances in Wireless Sensor Network Systems for Urban Drainage Monitoring

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**Abstract**

Urban drainages are important for evacuation of waste water in cities. It helps for the smooth running of the daily activities in the city and prevents proliferation of diseases. Drainage systems and construction methods have not evolved much in the past years. Due to population growth, urbanization and climatic changes, our urban drainages have become inefficient. Localized heavy rainfall causes overflow of drains that lead to floods resulting in major infrastructural damages and loss of lives. Obstruction due to solid waste prevents effective waste water evacuation. In this paper existing drainage monitoring systems are identified and their monitoring methods and technologies are analysed. Current drainage water monitoring methods such as the Rational method, the Modified Rational method, the SCS Runoff method, the Saint-Venant equation and the Manning's equation are not reliable and only provide estimated value for peak discharge and mean water velocity. Wireless sensor network systems for monitoring drains and rivers in different regions such as Birmingham, Brazil, Philippines and Mississippi are thoroughly discussed. Wireless sensors and microprocessor platforms that may be used for the urban drainage monitoring are evaluated. A systematic review of the research challenges for real-time monitoring of urban drainages is carried out. Furthermore, possible solutions that use advanced sensor technologies to detect overflow and obstruction in urban drainages are analysed. Indeed this paper provides a comprehensive assessment of technological advances in urban drainage monitoring systems.

**Keywords:** wireless sensor networks, urban drainage monitoring, water flow monitoring, overflow detection, obstruction detection

## 1. Introduction

In the Medieval Europe era, the sewers implemented were open ditches that followed the drainage pathway to meet rivers and other water bodies (De Feo *et al.*, 2014). Even in London and Paris, rivers were used as open sewers that carried all the wastewaters out of the city. This waste disposal method was prohibited in the year 1375 in London, while Paris started the construction of underground sewer in 1370, more specifically at the rue Montmartre. France continued its pursuit in the development of sewers and the first wastewater treatment plants started in the years 1930 in Paris.

During the 20th century, our sewer systems have not progressed a lot in design and consist mainly of three main types of collection systems; namely the sanitary wastewater collection systems, storm water collection systems and a combined wastewater and storm water collection systems (De Feo *et al.*, 2014). The design principles remain the same by dividing the town into separate areas and having different radial collectors from different regions of the town converging to a single location where the sewage begins. Each area comprises of short collectors and many sewers merges to a longitudinal collector of bigger size to accommodate the wastes of the small collectors.

Urban drainage systems have been helping mankind to construct highly modern cities since past 150 years (Arnbjerg-Nielsen *et al.*, 2013). Drainage system used for evacuating excess water from urban regions to prevent flood no more serve their purpose. The sources of excess water are mainly from rainfall and waste water from houses. Excess water from houses can be determined and has little ad hoc behaviour and variation. On the other hand, the amount of water from rainfall varies by significant amount. With evolution in time, we have progressed a lot in terms of determining the location and forecasting the amount of precipitation in several regions. The forecasting method is mainly based on statistical data collected over several years. But during the recent years, even our climate has constantly been changing, hence the need for real-time monitoring of the urban drainage system in cities.

In this paper, section 1 introduces the area of study of wireless sensor networks for urban drainages, Section 2 discusses about the problems with existing drainage systems and the cause of drainage overflow. Section 3 gives a detailed description of the different drainage water flow calculation methods such as the Rational method, the Saint Venant equation, the SCS Runoff method, the Modified Rational method and the Manning's equation. Existing systems that uses wireless sensors are analysed in Section 4. Section 5 highlights the technological advances in wireless sensors and comparatively analyses the different water level and water flow sensors. Section 6 examines on the problems encountered and provides possible solutions. Finally, Section 7 concludes the study of this research.

## 2. Problems with Existing Urban Drainage System

There has been recent flood that occurred in numerous part of the world. Unpredictable flood occurred in Queensland between 2010 and 2011, in Thailand in 2010, in China in 2012 and in Germany and Hungary in 2013 (Horita *et al.,* 2014). In India, the cities produce an average of 100,000 million litres of waste water per day (Elango and Usha, 2014). This huge amount of waste water has to be effectively evacuated to prevent overflow of the urban regions and also avoid propagation of tuberculosis and other airborne diseases.

### *2.1 Urban Drainage Design Issues*

Urban drainages have been designed based on historical information in the ancient times. But there has been little consideration that we are encountering major climatic changes and population growth that are affecting our globe. Based on the climatic variations that have occurred in several regions, it has been noticed that the design criteria taken into consideration in those ancient times are no more relevant. Several recent incidents have shown that drainages are not efficient. In most cities the amount of waste water can be estimated based on the population of the area (Balmforth *et al.,* 2006). Although during the drainage design the total waste water of the inhabitants residing in the city are already taken into consideration, there are other parameters which are difficult to estimate. For instance, population growth and urbanization are two parameters that affect the drainage system and require constant monitoring (De Feo *et al.,* 2014). People usually tend to move to cities to have better facilities and a better quality of life.

In the Calikut city of Kerala, more precisely in Palayam area, excess of water run-off is a threat to the environment (Needhidasan and Nallanathel, 2013). The Palayam region is a densely populated area and evacuation of the inhabitants in limited time is impossible. Palayam has encountered several occasions of flood due to its bad drainage design during which the population growth and terrain topology were not considered. Three main criteria to take into account for the design of urban drainage are:

- Functional requirements.
- Technical requirements.
- Social and economical considerations.

During the planning and design process, wastewater as well as storm water needs to be considered (Needhidasan and Nallanathel, 2013). The aim is to provide a reasonable degree of protection as it is neither practical nor economically viable for total elimination and control of flood. The worst case scenario is not taken into consideration. This gives room for intermittent high rainfall to overflow the drainage system causing loss of human lives and infrastructural damages.

### *2.2 Urban Drainage Overflow*

Overflow of urban drainage is an issue which is frequently encountered in several cities. The reasons vary from design issues to unpredictable high rainfall rate and obstruction in the drainage, which result in drainage overflow. Storm drains are used to evacuate excess rain and ground water from urban regions such as streets, parking lots and houses (Needhidasan and Nallanathel, 2013).

Combined sewer is one which collects water runoff and sanitary sewage into a single structure. Overflow of combined sewer is an important issue which is gaining impetuous. In India, the overflow of sewer has resulted in numerous health issues and environmental pollution (Elango and Usha, 2014). In Brazil, the floods encountered are very difficult to predict as technical parameters, such as the current level of water in rivers cannot be monitored. In such situation, there is not enough time to take the necessary preventive measures and this resulted in multiple infrastructural damages.

The city of Port-Louis, in Mauritius, has been experiencing recent floods. The Ruisseau du Pouce drains were cleared and enlarged for easy passage of water as it was prone to risk of overflow during high rainfall periods (Le Defi Media Group, 2013). On 30th March 2013, the Canal Dayot overflowed due to high rainfall rate. The overflow of the drainages developed into water current that carried away hundreds of vehicles. People were trapped inside buildings surrounded with water and the roads were impracticable. This unexpected incident caused panic in the city, major infrastructural damages and 11 persons lost their lives. Figure 1 shows the state of the Ruisseau du Pouce and Canal Dayot after being overflowed.

Figure 1. Ruisseau du Pouce and Canal Dayot after flood (Le Mauricien, 2013)

A total of 140.8 mm of rainfall was recorded for a duration of 4 hours (Hansard, 2013). Analysis carried out afterwards revealed that improper maintenance of drainages and solid wastes blocking the water passage contributed to this incident although it is not the main reason for the flood. In such a high rainfall environment, it was practically impossible to monitor the drainage status and to give a real-time feedback to the local population. An alert was declared at the last minute and the authorities were not in a situation to take appropriate measures to evacuate the excess water and safeguard the inhabitants of Port-Louis. The streets of Port-Louis were flooded within few hours. Figure 2 shows the Caudan Waterfront after the flash flood of 30th March 2013.


Figure 2. Caudan Waterfont few hours after the flash flood of 30th March 2013 (Le Defi Media Group, 2013)

*2.3 Impacts of Climatic Changes*

Climatic changes such as global warming have contributed to unpredictable precipitation at random locations. The model of forecasting based on historical data is no more reliable in our modern era. In the forthcoming years, the physical infrastructure of our drainage system need to be re-evaluated (De Feo *et al.*, 2014).

According to the U.N. forecast, cities that were previously safe can now face heavy rainfall which affects the evacuation capacity of storm water, drainage and sewerage infrastructure (De Feo *et al.*, 2014). Countries in the region of Asia, namely India, Bangladesh and China are in high risk of floods. Sweden, Finland and Russia, in the European region will also experience high rainfall in the forthcoming years. In 2002, Europe experienced a huge number of floods causing consequent damages (Trenberth, 2008). For the period of May to July 2007, England in turn encountered a heavy flood. Analysis made by Trenberth (2008) describes that the high rainfall is because of the increase in moisture level in certain regions. Humidity on the other hand did not vary much and was not considered to be a determining factor to create high precipitation rates. Like the example above, there are other climatic changes that are triggering huge amount of rainfall in many regions. The existing wastewater disposal mechanism in many countries will need major modifications to be able to contain the forthcoming high precipitation. Hence there is a high need for monitoring of urban drainage systems. Wireless sensors need to be placed at strategic locations in drains for monitoring of water level and water flow to detect overflow and obstructions.

### *2.4 Urban Drainage Limitations*

Our drainage system has been designed considering numerous factors but still they require constant re-evaluation to decrease the occurrence of urban drainage overflow. The world population is estimated to increase by 2 billion by 2050 (De Feo *et al.*, 2014). Thus there will be higher waste water produced which will lead to a higher demand of waste water disposal. The developing countries are already facing issues. India and countries in the African regions are encountering severe health problems due to disease proliferation. Old sewer and drainage systems, constructed to accommodate lesser inhabitants are still in use but do not serve their purpose.

Another factor to be considered is urbanization. Numerous predictions highlights that a higher number of people will tend to live in urban areas which will increase the waste water disposal (De Feo *et al.*, 2014). The existing sewer systems in the urban regions will not be able to accommodate these high growths in demands and the option of simply extending the existing drainage system is not feasible. Finding an appropriate solution for waste water disposal remains a challenge. Furthermore, the states of sewer systems in numerous cities such as England, Paris and Rome have degraded with time. EU environment legislation is forcing it members to upgrade their waste water systems for a better preparation to all the miscellaneous changes that can affect the volume of disposable waste water. However, countries of the Eastern Europe and Central Asia may not be prepared to face the new challenges.

Our existing drainage systems are not reliable to evacuate all the excess water volume caused by urbanization and population growth. Overflow of drains may cause major infrastructural damages and disease proliferation. Setting up of a wireless sensor system for monitoring the water level helps to detect drainage overflow within seconds. The system can thus raise an alarm for local authorities to take appropriate actions.

## 3. Drainage Water Flow Calculation Methods

There have been various methods developed by many physicians such as Emil Kuichling (Needhidasan and Nallanathel, 2013) and others which serve in determining the peak discharge or the mean velocity of waterflow in a drainage. Methods such as the Rational method and the St-Venant equation, require input parameters which are very complex to determine, thus making the results an approximation or estimation of the real value.

In many cases, the deviation of the calculated peak discharge or water velocity from the actual values is due to incorrect inputs. It has also been highlighted that the state of the drains changes with regards to time. Wireless sensors capturing real-time water level and water flow in the drains will output more reliable results that can be used for accurate overflow detections and predictions. In the section below, a study is carried out to analyse the existing methods and to highlight their benefits and drawbacks.

### *3.1 The Rational Method*

The Rational method is used to calculate the total discharge of water that a drainage system can hold up before overflowing (Proag, 2013). The Rational method takes several parameters into consideration namely the material type of the drainage system, the intensity of rainfall and the size of the drainage.

The formula for the Rational Method is

$$Q = 0.278\ c\ i\ A \tag{1}$$

where;

- Q = Peak discharge into drainage ($m^3/s$)
- c = Runoff coefficient. Varies depending on the material type (dimensionless)
- i = Intensity of rainfall. Varies depending on the environment (mm/hr)
- A = Catchment area. The area of water that flows into the drainage ($km^2$)

The Rational method is applied based on the following assumptions (Proag, 2013):

- There is uniform area distribution of rainfall across the whole catchment.
- The rainfall intensity is constant for at least a duration equal to the time of concentration, $t_c$.
- The peak flow occurs when the rainfall intensity lasts at least as long as $t_c$.
- C, the runoff coefficient, remains constant throughout the storm duration.
- The return period of the peak discharge, Tr, is the same as that of the rainfall intensity.

The intensity of the rainfall can be measured directly or even calculated by recording the amount of rainfall per hour. The peak flow in a drain is calculated by the Rational Method for appropriate design and construction of the drainage system. There have been various discussions, by Theodore G. Cleveland (Cleveland *et al.,* 2011) and others, about the usage of Rational method, SCS (Soil Conservation Service) hydrograph method or the modified Rational method. The Rational method has certain limitation which is due to the assumptions used in the formula Q = 0.0028 C i A. The rainfall intensity varies in real-time while in the Rational method it is assumed to be constant throughout the time of concentration. The most challenging part in the Rational method is to calculate the runoff coefficient of the catchment area. It comprises of variables such as earlier precipitation, land pattern, soil moisture, water infiltration and terrain inclination.

Considering the different parameters used in the Rational Method, in can be deduced that the latter has the following drawbacks:

- Cannot give the real time status of the level of water inside the drainage.
- Cannot detect if there is any obstruction inside the drainage.
- Does not cater for the fact that the peak discharge depends on the inclination of the slope and the terrain type.

These parameters that have not been considered change the peak discharge in the drainage by a significant amount, hence gives an inappropriate forecasting. Furthermore the Rational method is based on historical data. As climatic changes are resulting into high deviation in the prediction of rainfall location and intensity, the Rational method is no more reliable.

*3.2 The Saint-Venant Equation*

The Saint-Venant equation is used to model the flow in an open canal in sewer pipes. It is based on physical principles of mass conservation of energy (Cleveland *et al.,* 2011). The equation is simplified by decomposing the sewer network into several virtual and real tanks. The formula is given in Figure 3 below.

$$v_{n_1}(k+1) = v_{n_1}(k) + \Delta t \varphi_{n_1} S_{n_1} P_{n_1}(k) + \Delta t \left( \sum_j q_{\text{in}}^{n_1 j}(k) - \sum_h q_{\text{out}}^{n_1 h}(k) \right)$$

Figure 3. Saint-Venant equation (Ocampo-Martinez *et al.,* 2013)

Where

- n = Virtual tanks
- $\partial_{n1}$ = Ground absorption coefficient of the $n^{1\text{-th}}$ catchment
- $S_{n1}$ = Surface area
- P(k) = Rain intensity at each sample with a sampling time $\Delta t$
- $q_{v\ in/out}$ = The flow through control gates

Control gates are used as control devices to either divert the flow of the sewage (diversion gates) or stop the flow of the sewer (detention gates). In Saint-Venant equation, nodes are considered to be points in the network where the sewage can be propagated or merged (Ocampo-Martinez *et al.,* 2013).

The Saint-Venant equation is highly complex and all parameters cannot be monitored. It does not cater for real time parameters, such as rainfall variations and localized precipitation. The equation requires several assumptions for easier understanding and control. For instance, the tank outflow is assumed to be proportional to the water volume currently stored within the tank (Ocampo-Martinez *et al.,* 2013). The underlying simplifications and assumptions make the Saint-Venant equation unreliable for real-time monitoring and predictions.

*3.3 The SCS Runoff Method*

The SCS Runoff method is used to estimate the peak discharge for a 24-hr design storm. It was developed by the

United States Soil Conservation Service (Needhidasan and Nallanathel, 2013). The SCS Runoff method calculates the peak discharge based on the drainage inputs, the unit hydrograph and the soil characteristics. The soil type are categorised as shown below:

- Group A: Deep sand, deep loess and aggregated silts.
- Group B: Clay loams, shallow loess, sandy loam.
- Group C: Clay loams, shallow sandy loam, soils low in organic content, and soils usually high in clay.

Inputs required for calculating the peak discharge are rainfall amount, the potential maximum retention after runoff begins and the initial abstraction. The formula for calculating the runoff is shown in Equation 2.

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S} \qquad (2)$$

Where:

- Q = Runoff.
- P = Rainfall.
- S = Potential maximum retention after runoff begins.
- $I_a$ = Initial abstraction.

The initial abstraction is found to be highly variable depending on the terrain characteristics and is difficult to measure accurately. It is the summation of all the water losses which occurs before runoff and consists of water retained in surface depression, water cut off by vegetation, water evaporated into the atmosphere and water infiltrated into the soil (Needhidasan and Nallanathel, 2013). Experiments carried out has highlighted that for small agricultural watersheds, the initial abstraction can be determined using the formula $I_a = 0.2S$, where $I_a$ = the initial abstraction and $S$ = the potential maximum retention after runoff begins. The potential maximum retention after runoff is dependent on the soil and cover conditions of the watershed linked to the CN Number (SCS Runoff Curve Number). The first drawback of the SCS Runoff method is that the initial abstraction cannot be precisely computed, hence making the peak discharge only an estimation of the exact value. Secondly, soil characteristics should be determined accurately to avoid deviation from the actual peak discharge amount.

### *3.4 The Modified Rational Method*

The Modified Rational method is an extension of the Rational method for situations where storms have a greater duration than the normal time of concentration. In such scenarios, the volume of the runoff will be greater but with a lower peak discharge (Cleveland *et al.*, 2011). The Modified Rational method is mostly used for design storage with watersheds of up to 20 to 30 acres. The formula for the Modified Rational method is shown in Equation 3.

$$Q = 0.0028\ C\ i\ A \qquad (3)$$

Where:

- Q = The peak discharge ($m^3$/s).
- C = The runoff coefficient (dimensionless).
- i = The intensity of rainfall, based on the duration of the rainfall (mm/hr).
- A = The catchment area ($km^2$).

The Modified Rational method results into a hydrograph having the peak discharge against time. The hydrograph is in the trapezium form as shown in Figure 4.

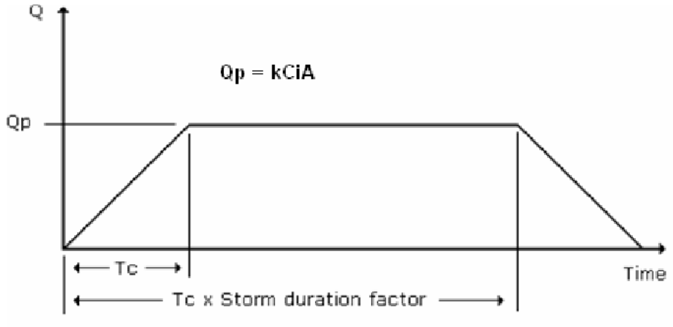



Figure 4. Hydrograph for Modified Rational method (Needhidasan and Nallanathel, 2013)

The value of the runoff coefficient (C) varies based on the terrain type and inclination and has to be correctly determine by the engineer. The various values for the runoff coefficient are shown in Table 1.

Table 1. Runoff coefficient for Rational method (Thompson, 2006)

| Description | Runoff coefficient |
|---|---|
| Business | |
| Downtown Areas | 0.70 – 0.95 |
| Neighbourhood Areas | 0.50 – 0.70 |
| Residential | |
| Single-family | 0.30 – 0.50 |
| Multi-family detached | 0.40 – 0.60 |
| Multi-family attached | 0.60 – 0.75 |
| Residential suburban | 0.25 – 0.40 |
| Apartments | 0.50 – 0.70 |
| Parks, cemetaries | 0.10 – 0.25 |
| Playgrounds | 0.20 – 0.35 |
| Railroad yards | 0.20 – 0.40 |
| Unimproved areas | 0.10 – 0.30 |
| Drives and walks | 0.75 – 0.85 |
| Roofs | 0.75 – 0.95 |
| Streets | |
| Asphalt | 0.70 – 0.95 |
| Concrete | 0.80 – 0.95 |
| Brick | 0.70 – 0.85 |
| Lawns; sandy soils | |
| Flat, 2% slopes | 0.05 – 0.10 |
| Average, 2% - 7% slopes | 0.10 – 0.15 |
| Steep, 7% slopes | 0.15 – 0.20 |
| Lawns; heavy soils | |
| Flat, 2% slopes | 0.13 – 0.17 |
| Average, 2% - 7% slopes | 0.18 – 0.22 |
| Steep, 7% slopes | 0.25 – 0.35 |

*3.5 The Manning's Equation*

During the year 1889, numerous drainage water flow formulae such as the Chézy and Eytelwein, Weisbach, Saint-Venant, Du Buat and Kutter were under study (Bertrand-Krajewski, 2006). After different comparisons with the existing formulae, Manning's equation was published in 1890 for the calculation of the mean water velocity for an open channel. The formula for calculating the mean water velocity is as shown below in Equation 4.

$$V = \frac{k}{n} R^{2/3} S^{1/2} \tag{4}$$

Where:

- $V$ = The mean velocity (m/s or ft/s).
- $k$ = 1.49 for U.S customary units and 1.00 for SI units.
- $n$ = Manning's roughness coefficient.
- $R$ = Hydraulic radius (m or ft).
- $S$ = Friction slope (m/m or ft/ft).

Using the formulae R = A/P; where $R$ = the hydraulic radius, $A$ = the cross-sectional area of flow, $P$ = the wetted perimeter, and $Q = A * V$; where $Q$ = the peak discharge, $A$ = the cross-sectional area of flow, $V$ = the mean velocity, the Manning's equation can be expressed as in Equation 5 to calculate the peak discharge in a open channel.

$$Q = \frac{k}{n} \frac{A^{5/3}}{P^{2/3}} S_0^{1/2} \tag{5}$$

Where:

- Q = The peak discharge.
- $k$ = 1.49 for U.S customary units and 1.00 for SI units.
- A = The cross-sectional area of flow.
- n = Manning's roughness coefficient.
- P = Maximum storm rainfall within a day (mm).
- S = The potential maximum retention.

The Manning's roughness coefficient varies based on the material type of the open channel. The values for the roughness coefficient are as shown in Table 2. Even in the modern time, it is difficult to accurately compute the potential maximum retention and the service of an expert engineer needs to be sought to precisely determine the manning's roughness coefficient.

Table 2. Few typical values of Manning's roughness coefficient, n *(CIVE 2400)*

| Channel type | Surface material and form | Manning's n range |
|---|---|---|
| River | Earth, straight | 0.020 – 0.025 |
| | Earth, meandering | 0.03 – 0.05 |
| | Gravel (75 – 150 mm), straight | 0.03 – 0.04 |
| | Gravel (75 – 150 mm), winding | 0.04 – 0.08 |
| Unlined canal | Earth, straight | 0.018 – 0.025 |
| | Rock, straight | 0.025 – 0.045 |
| Lined canal | Concrete | 0.012 – 0.017 |
| Lab. Models | Mortar | 0.011 – 0.013 |
| | Perspex | 0.009 |

## 4. Existing Urban Drainage Monitoring Systems

This section analyses existing monitoring system which have been implemented for urban drainages. The situational analysis, system design, methods and techniques used and implicated sensors in the systems are discussed.

### *4.1 Evaluation of Drainage using Agent-Based Models*

Agent-based models were used for evaluation of existing urban drainage system in the city of Birmingham, in England, having a surface area of 267.77 $km^2$ (Sanchez *et al.*, 2011). Birmingham is one of the most populated cities with an estimated population growth of 1,028,700 in 2009. For evaluation of the current system and forecasting of the drainage infrastructure for the future years, agent-based model, more specifically the cellular automata model is used. The Dinamica software simulates the platform for urban dynamics. It uses the landscape map of the area matching to the Corine Dataset from the European Spatial Agency which consists of ancillary maps with static and dynamic variables (Sanchez *et al.*, 2011). All the set of maps were converted to raster maps so that all maps are synchronized within the same coordinates. With this analysis, the most suitable area for changes can be identified. The methodology used for the evaluation and urban change prediction of the area is shown in Figure 5.

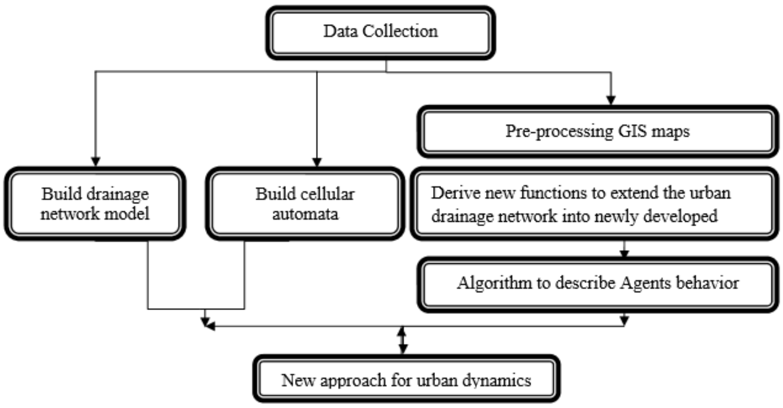



Figure 5. Methodology used for evaluation and drainage forecasting of Birmingham (Sanchez *et al.*, 2011)

The combination resulted into several maps giving detail information of slopes, roads, motorways, rail network, rivers and canals and drainage network. The input maps datasets used in the Dinamica Ego software are shown in Figure 6.

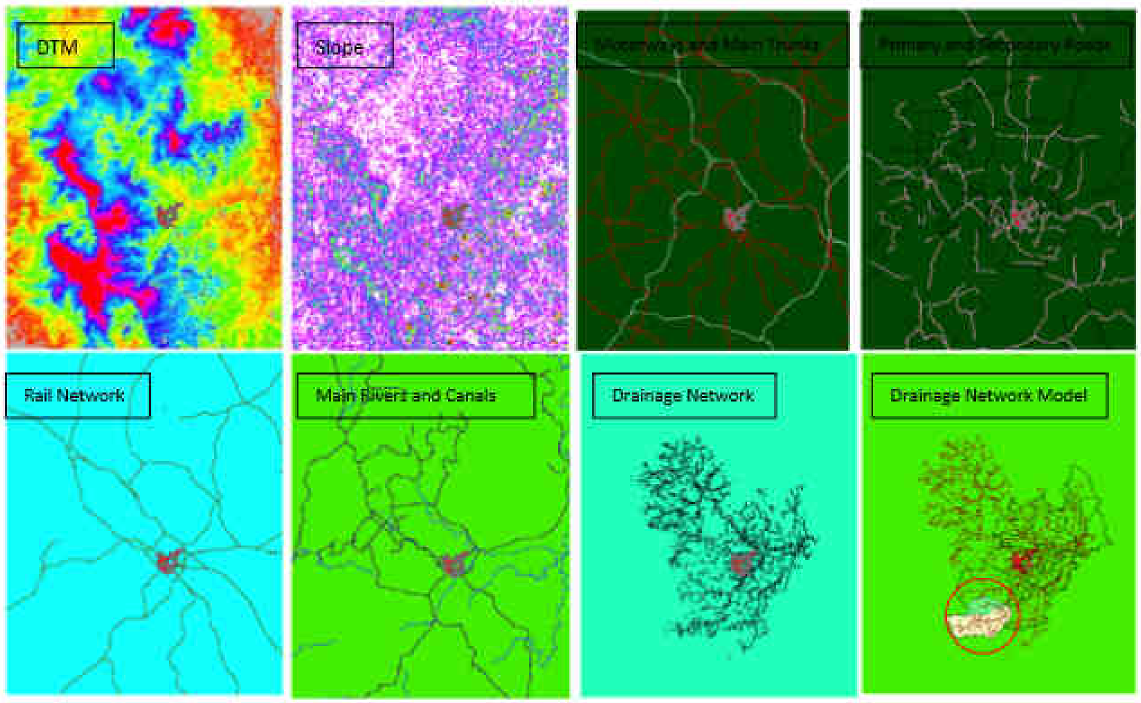



Figure 6. Maps used in Minamica Ego (Sanchez *et al.*, 2011)

The NSGA II Generic algorithm was used for the linking between the calibration of the model, the patcher and matrix that regulates the percentage of change (Sanchez *et al.*, 2011). A total of 1725 evaluations consisting of 112 generation and 15 populations with different landscapes are used each time. Using the Arcgis 9.3 software, a spatial analysis was carried out by utilizing corridors along the main collectors, with pipes having diameter greater than 500 mm. The result was mapped on the landscape to obtain a distribution of the land use area per category that directed into each corridor. The above methodology and results gathered are used to predict the addition and position of new pipes for appropriate evacuation of water.

### *4.2 Real-Time Flood Monitoring using Satellite-Based Estimation*

Flood becoming more and more frequent has contributed to more than 55% of the total natural disasters in the world. The Global Flood Monitoring System uses satellite based precipitation information, which has been running for few years before, to estimate the flood occurrence in the concerned region (Wu *et al.*, 2014). The system has been tested by placing rain gauges along the Mississippi valley and the former compares the prediction model along with the recorded data. The Global Flood Monitoring System has been used to predict flood in region of north India during 15 June 2013 and 20 June 2013, and over the Mississippi valley during April to June 2013. The flood in north India was reported as a huge one where more than 1000 people lost their lives.

Global Flood Monitoring System uses Land Surface Model. The Variable Infiltration Capacity model is coupled with dominant river tracing-based runoff-routing model to form the Dominant River Tracing-Routing Integrated with VIC Environment (DRIVE) model system (Wu *et al.*, 2014). Based on the resolution from the satellite, around 1 km hydrographic inputs, Global Flood Monitoring System uses a grid system with parameterization for each routing model element. The results used in DRIVE for precipitation estimation have been captured and analysed over a period of 15 years. The system has reliably good precision with a percentage of approximately 87% of correct flood detection and a false alarm of around 0.85 for flood events. A sample of the Dominant River Tracing-Routing is shown in Figure 7 below.

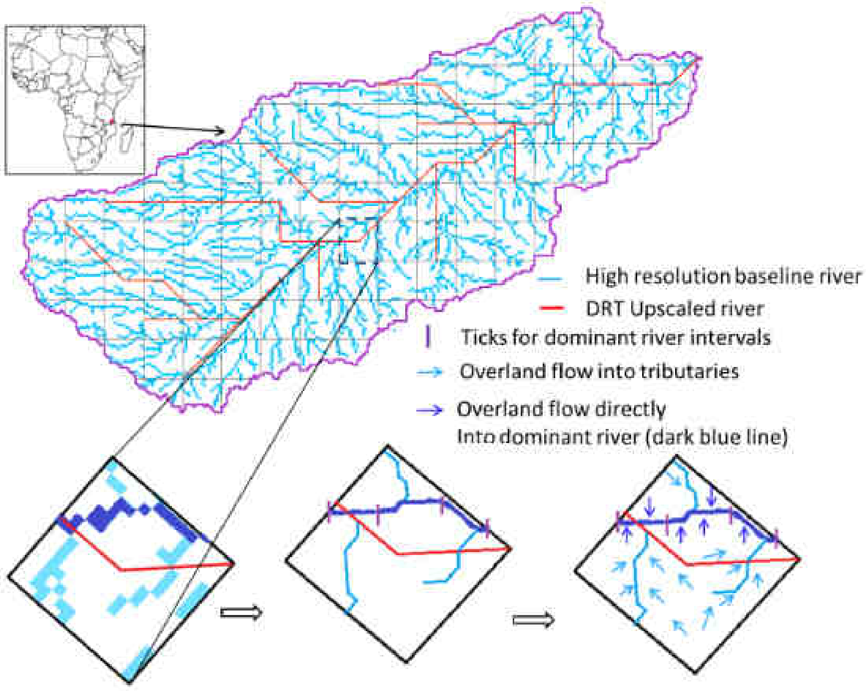



Figure 7. Sample of Database River Tracing-Routing (Ani *et al.*, 2013)

To validate the accuracy of the system, Global Flood Monitoring System was also tested against global streamflow observations from Global Runoff Data Centre. It was also analysed that the Manning coefficient contributes to a major part on the output of the prediction system.

*4.3 Drainage System using Zigbee Sensors – Philippines*

The Metro Manila, situated in the Philippines, is visited by frequent floods. The causes of these floods are mainly due to the clogging of the drainage system (Ani *et al.,* 2013). If not monitored, overflow of the drainage can result to damage of properties and death of civilians. The sewer is used to evacuate household and human wastes whereas the drains are used to handle waste water coming from streets, factories or creek. The Metro Manila Development Authority (MMDA) is responsible for the construction and proper functioning of the drainage system.

Water level sensors were used for monitoring the water level in the drains. Sensors were placed at three different heights in the drainage system (Ani *et al.,* 2013). If there is any obstruction such as bottles or plastic, the sensor will not be able to read the water level. In case the sensor is faulty, it would display 'sensor error'. Through this technique, any obstruction blocking the drainage system can be easily detected. The ZigBee sensors offered numerous benefits such as low complexity, low cost, low power consumption but it has as drawback a low transmitting rate (Ani *et al.,* 2013). In addition, ZigBee sensors are highly reliable and easily adapted to ad-hoc network. ZigBee sensors operate in the frequency 868 MHz, 902-928 MHz, and 2.4 GHz. A wireless personal area network (WPAN) was used for connection of the sensor, the microcontroller, and the systems. The block diagram in Figure 8 shows the connectivity between the water level sensors, the microcontroller, the ZigBee sensors and the PC server.

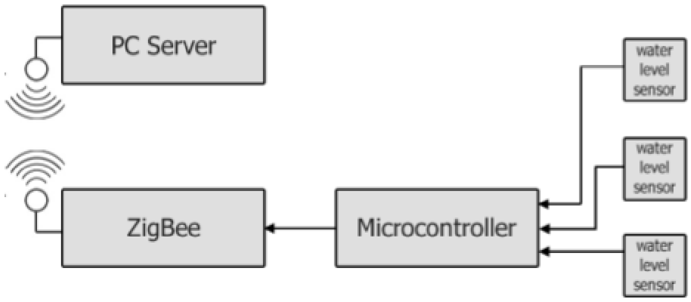



Figure 8. Block diagram showing data flow between water level sensors, microcontroller, ZigBee sensor and PC server (Ani *et al.,* 2013)

*4.4 Real-Time Flood Risk Monitoring - Brazil*

Brazil has been experiencing frequent flood in Sao Paulo, Rio de Janeiro and Santa Catarina (Horita *et al.,* 2014). The reasons identified for the flooding is climatic changes resulting into unpredictable high rainfall rates in unexpected regions. Water overflowing from rivers was causing much trouble to the nearby cities. The government along with official agencies and the general population went towards a flood monitoring approach by placing sensors along the river beds. The sensors' data are captured, treated as performance indicators, and sent to a geosensor dashboard, which was built from an open-source framework. The system makes use of ZigBee motes sensors which are connected to Sensor Observation Service with GeoExtAPI/OpenLayers. This offers a higher degree of flexibility and scalability to the system. Figure 9 below shows the layers interaction within the AGORA-GeoDash system. A Service Oriented Architecture (SOA) is responsible for the interaction between the layers.

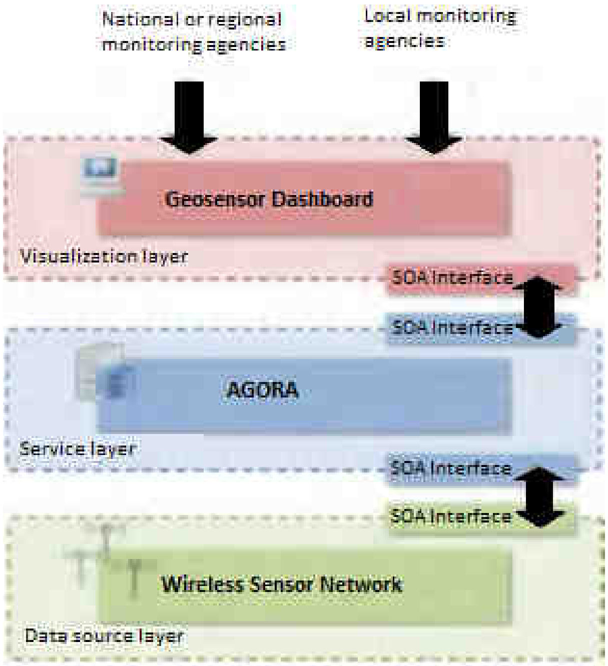



Figure 9. Block diagram of AGORA system (Horita *et al.*, 2014)

The Data Source Layer consists of wireless sensors that capture the height of water level, speed of water, temperature of water and level of pollution from rivers (Horita *et al.*, 2014). The sensors connected to a wireless sensor network, transmits the gathered data to the Service Layer. Fusion, transformation and sharing of the data are done through AGORA in the Service Layer. The Service Oriented Architecture (SOA) offers services that allow the integration of data. The Visualization Layer which comprises of the Geosensor Dashboard displays the information to emergency services and official agencies such as fire, police and civil defence. The sensors were placed at strategic locations which have already been flooded in the past. Figure 10 shows a map of the Monjolinho river with sensors placed at 3 strategic locations sending data to the base station.

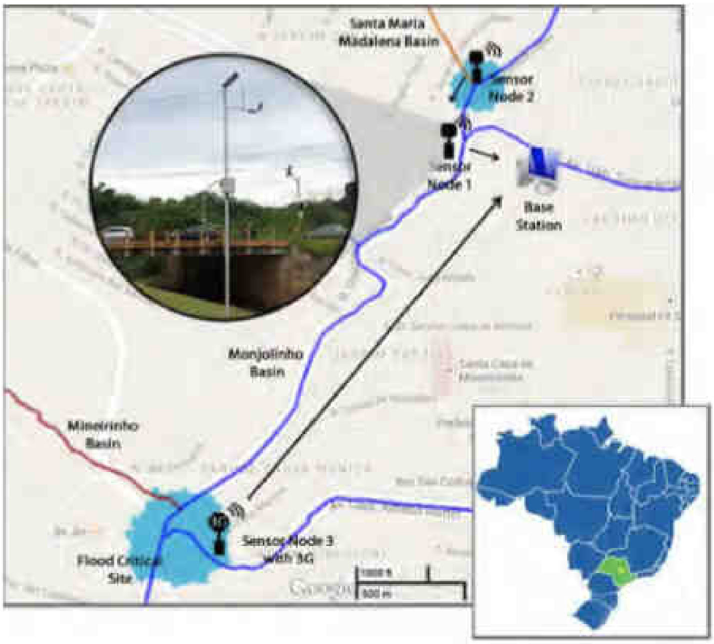



Figure 10. Wireless sensor dissipated on the bank of Monjolinho river (Horita *et al.*, 2014)

An extract of the Geosensor Dashboard of AGORA-GeoDash is shown in Figure 11. The section labeled 1 gives a map of the monitoring zone with the red and green dots showing the position of the sensors (Horita *et al.*, 2014). Section 2, 3 and 4 are the parameters that are being monitored in real-time by the dissipated sensors. The blue lines give the actual height of the level of water in the river and the red lines represent the bank of the river.

Overflow can be known when the blue line crosses the red line. Section 5 generates a report of the level of the water for a given period of time. This is mainly used for analysis of historical data. Section 6 represents the level of water for the last hour and section 7 contains a picture taken near the river bank by installing a camera on the sensor. Lastly, section 8 indicates the Hazard Index (HI) which is a combination of water level and water velocity. HI represents vulnerability to loss with regard to human stability in flood flows.

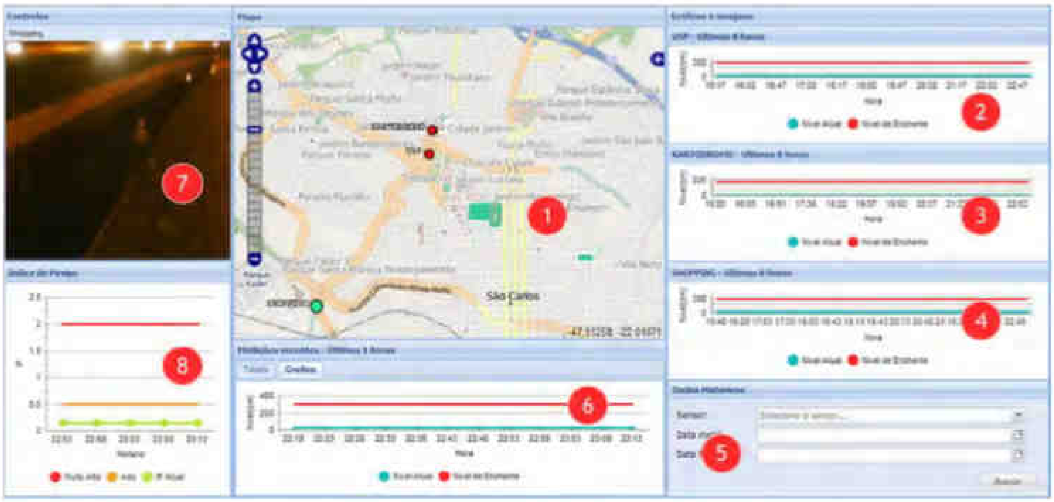


Figure 11. Screen extract of Geosensor Dashboard of AGORA-GeoDash (Horita *et al.*, 2014)

## 5. Technological Analysis

Environment changes are triggering high variations in the rainfall intensity and water infiltration rate. Debris and solid waste carried by the water flow can any time obstruct the water passage in drains. Traditional methods; namely the Rational method, the Saint-Venant equation, the SCS Runoff method, the Modified Rational method and the Manning's equation, require real-time and precise data for overflow detection and prediction. Capturing real-time information to evaluate the state of the drainage system permits a constant monitoring. Wireless sensors placed a strategic locations in the drainage system may allow capturing real time parameters. These parameters may be used as input for a predefined model to detect overflow. The need to evacuate excess urban water is a must to enable the smooth flow of activities in cities, or in the worst cases, the population is evacuated in a timely manner. In order to take judicious actions, the forthcoming flood needs to be predicted, giving the authorities enough time to plan their emergency response tasks. Sanchez *et al.*, (Haestad Methods, 2002) discusses about the usage of agent-based model and cellular automata in evolution of urban regions and to better understand the pattern and mechanism behind urban dynamics. The model uses information from urban drainage system as a feedback to urbanization and for prediction of urbanization impact on urban drainage system in the coming years. Wireless sensors, appropriately programmed and calibrated are used to detect overflow of rivers and drains. This section discusses the characteristics and capabilities of sensors that are used for monitoring of urban drainages.

### *5.1 Technological Advances in Sensors*

Wireless sensors have evolved significantly in the last decade by reducing their size and doubling their power. Sensors have become more robust and have the ability to resist extreme environmental conditions. Libelium develops a wide series of sensors that can be combined and customized to match the users' need. One of these systems has been developed as a pilot project in a touristic port in Greece (Libelium, 2016). The system consists of three parts; first to control the water quality, second to detect height of the sea surface and the height to reach the port, and third to monitor weather conditions and to monitor the presence of water vessels in berths or berth positions. For monitoring of the sea level and weather conditions, the system uses liquid level sensor probes. The presence sensor (PIR) probe offers the functionality to measure the height of the sea surface and the height to reach the port. It also gives information with regards to the waterflow rate at the port. The Waspmote Plug & Sense, Sensor Platform and Meshium Gateway is used in the system to exchange data using the TCP/IP 802.15.4 communication protocol. The system also uses Firmware technologies for cloud service and dedicated agent. The captured data is processed and displayed on an online application for end users. Figure 12 shows how the

Libelium sensors and gateway are installed and how the sensors communicate in Patras port in Greece.

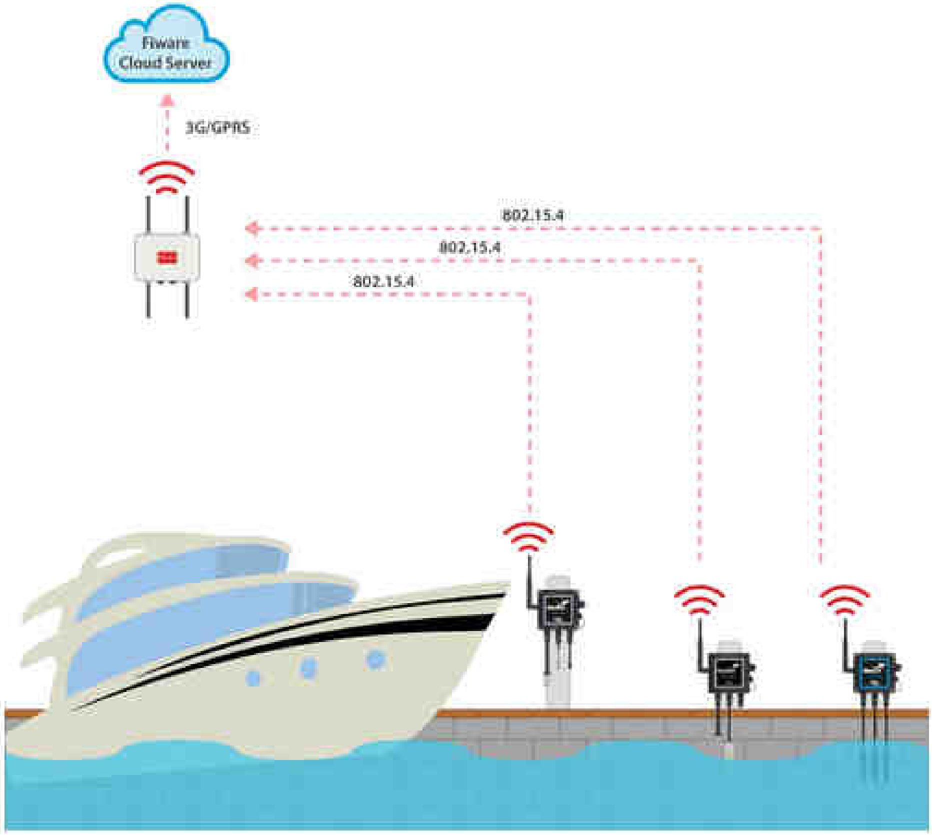



Figure 12. Libelium sensors and gateway deployed in Patras port (Libelium, 2016)

Another system proposed by Libelium consists of waspmotes connected to an event sensor board to monitor water level and an agriculture sensor board to monitor weather conditions (Libelium, 2011). These combined systems offer a system for detection of flood in smart cities. By using radio links in the frequency bands of 2.4GHz, 900MHz, 868MHz and the 802.15.4/Zigbee protocols, the sensors can communicate over long distances. Libelium sensor can easily be mounted on pylons and also connected to a battery which can be recharged by solar panels. Figure 13 shows the events sensor board and the agriculture sensor board.

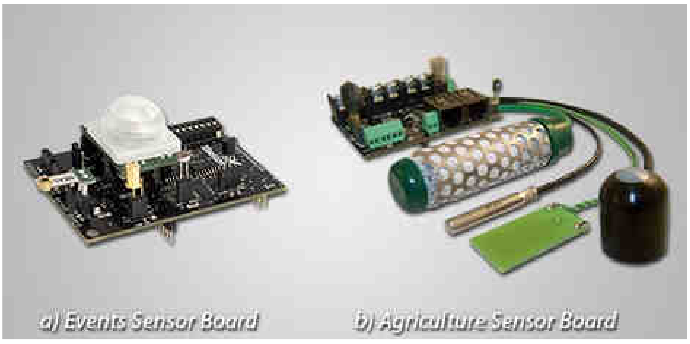



Figure 13. Event sensor board and agriculture sensor board (Libelium, 2011)

The combination of the event sensor board and agriculture sensor board offers a suitable solution for flood detection in cities. But the challenge still remains in adapting these systems in the monitoring of urban drainage and predicting drainage overflow situations. One difficulty is that drainage systems in various cities are poorly maintained and waterflow carries a lot of solid waste and debris on their path which may affect the reading of the sensors. In such situations, the sensor can be placed in grilled cage to prevent solid waste and debris to alter the actual reading and also prevent intruders to tamper with the sensors. The metal container on the left in Figure 14 has size 37"/42"/48" and is made with heavy duty material and is readily available (Ebay, 2016).

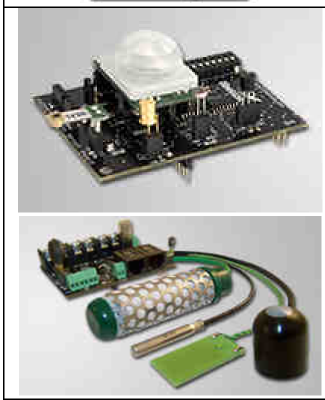
 

Figure 14. Metal crates available online (Ebay, 2016)

### *5.2 Water Level Sensors*

The section below gives an overview of the different water level sensors available on the market. The sensors can be used to capture the level of water in the drainage and these data can be transmitted through wireless sensor networks. Table 3 below gives an overview of the different water level sensors that are available.

Table 3. Water level sensors available on the market

| **Water Level Sensors** | | |
|---|---|---|
| **Sensor picture** | **Brand/ Company** | **Description** |
|  | ToughSonic – Senix corporation (SenixCorporation, 2016) | • Used in highly sophisticated environmental and industrial applications.<br>• Measures water in ponds, streams, canals and ocean.<br>• Uses satellite, cellular or radio communications to transmit data to centralized management system.<br>• Provides accuracy, long-term durability, digital communication and rapid time-to-first measurement speed. |
|  | Libelium (Libelium, 2011) | • Cost effective, scalable and flexible.<br>• Generates alert through SMS or internet database posting.<br>• Batteries recharged with solar panels.<br>• Uses outstanding radio links in frequency bands of 2.4GHz, 900Mhz and 868Mhz using 802.15.4/Zigbee protocols. |
|  | TE Connectivity Ltd (TE Connectivity, 2016) | • Offers protection from lightning.<br>• Available in analogue and digital output.<br>• Adapted to any data system.<br>• Uses self-powered units with onboard memory for long term deployment.<br>• Uses in lakes, rivers, estuaries, and aquifers worldwide.<br>• Accuracy ranges from 1.00% to 0.05% full scale |

*5.3 Water Flow Sensors*

Water flowing in drains carries numerous waste and solid materials such as plastic, mud, pebbles, branches and leaves. Open drains are most prone to be obstructed preventing the normal flow of water for evacuation (Trenberth, 2008). Obstruction can be determined by measuring difference in the water flow between two end points. Placing wireless sensors at different strategic point in the drains will capture the water flows, which can be later used for computation. Table 4 gives an overview of the water flow measuring sensors that are readily available on the market.

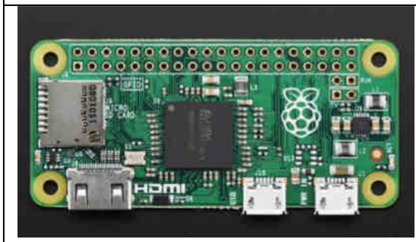
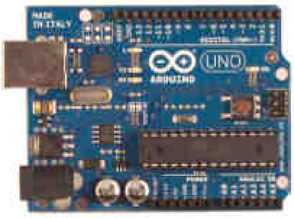
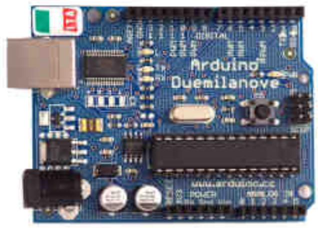
Table 4. Water flow sensors available on the market

| **Water Flow Sensors** | | |
|---|---|---|
| **Sensor picture** | **Brand/ Company** | **Description** |
|  | Libelium (Libelium, 2011) | • Cost effective, scalable and flexible.<br>• Generates alert through SMS or internet database posting.<br>• Batteries recharged with solar panels.<br>• Uses outstanding radio links in frequency bands of 900Mhz and 868Mhz using 802.15.4/Zigbee protocols. |
|   | Atrato (Atrato, 2016) | • Used in medical, industrial, laboratory and pharmaceutics.<br>• Accuracy up to margin of 1.5%.<br>• Can be connected to a laptop or computer to measure the waterflow. |
|  | Rosemount (Rosemount, 2016) | • Used in agricultural field, refineries and water treatment plants.<br>• Compatible with numerous Rosemount sensors.<br>• Has integrated fault diagnostic system.<br>• Transmit data to a computer through a smart wireless gateway.<br>• Update rate between 8 seconds and 60 minutes.<br>• Powered by 2.25 Volts at 3.5 mA; 1 Volt at 25mA. |

*5.4 Microprocessor Platforms*

Data captured by wireless sensor need to be saved and require pre-processing. This activity is also known as data aggregation, where processors process the information obtained from sensor nodes in summarized format and transmits the latter to a base station. Data aggregation reduces the size of the data package and minimizes power consumption. Table 5 gives an overview of the microprocessor platforms that are commonly used for data processing.

Table 5. Microprocessor platforms on the market

| **Microprocessor platforms** | | |
|---|---|---|
| **Microprocessor platforms picture** | **Brand/ Company** | **Description** |
|  | Raspberry Pi Zero (Adafruit , 2017) | • Small and thin (65 mm long x 30 mm wide x 5 mm thick).<br>• 512 MB of RAM.<br>• Micro SD card holder in push-pull style.<br>• HDMI video out.<br>• Audio out.<br>• Can easily be connected to a computer through USB port.<br>• Can easily be connected to sensor nodes via USB ports. |
|  | Arduino (Arduino, 2017) | • Microcontroller built on the ATmega328.<br>• Contain 14 digital input/output pins (of which 6 can be used as PWM outputs).<br>• Input voltage: 6-20V (limits) and 7-12V (recommended).<br>• 2 KB of SRAM .<br>• 1KB of EEPROM.<br>• 16 MHz clock speed.<br>• Can be easily powered via a USB connection or with an external power supply. |
|  | ZigBee (2008 Digi International Inc, 2017) | • Compatible with computers and other microcontrollers.<br>• Easy connection to USB explorer, explorer dongle and serial explorer.<br>• RF Data Rate: 250 Kbps.<br>• Indoor Range: 90 m<br>• Outdoor Range: 1.6 km<br>• Frequency Band: 2.4 GHz<br>• Serial Data Rate: 1200 bps – 1 Mbps<br>• Supply Voltage: 3.0 – 3.4 VDC |

## 6. Research Challenges and Solutions

The analysis carried out in this paper shows that urban drainages are highly prone to overflow due to various conditions. Given that we cannot control environmental parameters, one possible method to minimize the damages caused is by constantly monitoring the situation of the drains. Traditional methods cannot be used for such level of monitoring due to numerous practical restrains. This section focuses on the research challenges that need to be tackled for the provision of a viable solution for monitoring urban drainage systems.

### *6.1 Topology Coverage and Routing Issues*

Wireless sensor network topology suitable for urban drainages is still a challenge given the characteristics of the urban drainage system. Topology of wireless sensor networks is selected in such a way that the sensing area is fully covered. The number of nodes to be used is highly dependent on the area to be covered, the selected topology, the routing protocols to be used, the landscape of the sensing area and the lifespan of the observation period. Sink holes or black holes are regions in a wireless sensor network where there are no nodes available or the sensor node present in that region cannot form part of the routing nodes due to various reasons (Wood *et al.,* 2003). It prevents a sensor node in a specific area to sense by formation of a black hole that triggers loss of data within the sensing region and hence can make the final outcome unreliable.

One solution to sink holes problem is using algorithms such as geographical greedy forwarding. Formation of black holes during geographical greedy forwarding is less probable as the malicious node needs to broadcast at different positions in order to be the next hop (Wood *et al.,* 2003). Another solution is implementing a mechanism where the nodes need authorization to exchange routing information but this would require higher computation and communication overhead hence raising the concern of scalability and power consumption in broad sensing areas. Energy consumption on the other hand can be decreased by using the Span algorithm which adaptively chooses coordinators from all nodes forming a routing backbone and turn off the remaining nodes for power saving purposes (Chen *et al.,* 2001). Span is a power saving topology maintenance algorithm and is applicable for multi-hop and ad-hoc wireless sensor network.

Routing protocols are selected based on the topology of the dissipated nodes. Routing protocols normally consumes high energy which decreases the lifespan of the wireless sensor networks. Therefore, energy-efficient algorithms need to be explored. The Geographic and Energy Aware Routing (GEAR) algorithm routes a packet towards its region of interest (Yu *et al.,* 2001). It has high efficiency when the area to be covered is a small portion of the total region. If the region of coverage increases, the efficiency decreases by high percentages. Power control mechanism determines the correct energy required for effective data transmission. Another routing algorithm known as the COMPOW method uses distributed protocol to determine the minimum common transmitting range in a homogeneous network by ensuring network connectivity (Narayanaswamy *et al.,* 2002).

### *6.2 Overflow Detection in Drainage*

One of the main challenges in an urban drainage monitoring system remains the method for detecting the drainage overflow. Figure 15 illustrates the situation of a drainage overflow. Thus a mechanism has to be implemented to detect the overflow by properly positioning and calibrating the sensors.

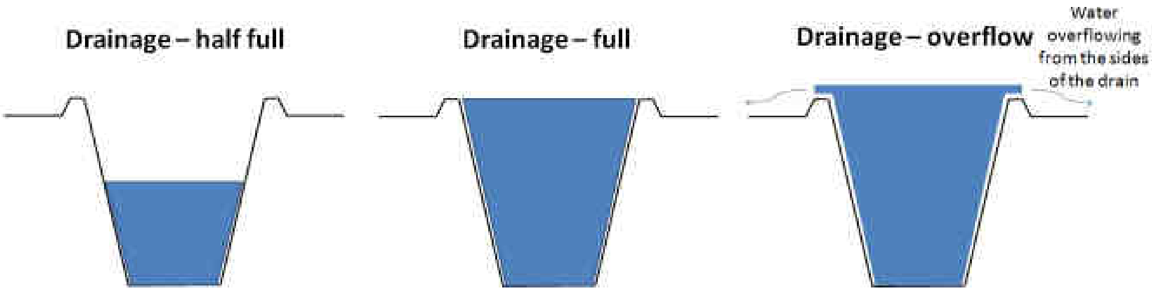



Figure 15. Water overflowing from the sides of the drain

One possible method is to place sensors at different vertical positions in the urban drainage as shown in Figure 16. For example, three sensors can be placed at different vertical levels in the drain; low, medium and high. As the high level sensor detects water, this shows that the drain is being overflowed. Another method for detecting drainage overflow is by using water level sensors however the drain depth must be known. The water level sensor will be placed at specific position over the drain. As the water level exceeds the depth of the drain, this indicates overflow.

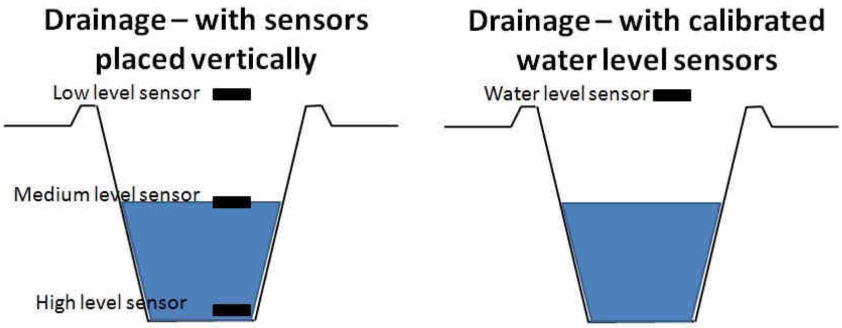



Figure 16. Detecting drainage overflow through sensors

The mechanism explained above is simple and reliable for detection of overflow in drainage and requires minimal computation. The only drawback is that several sensors will be required, taking an average of three sensors per dissipated location. Hence the investment on wireless sensors can be high depending on the sensors' price.

*6.3 Obstruction Detection in Urban Drainage*

Rainfall carry trashes along with dirt and mud to drainage system where solid wastes causes obstruction to the water passage, hence preventing proper evacuation of excess water. Inflow rate greater to the outflow rate cause a rise in the water level which results in overflow. Thus, early detection of obstruction will give enough time for local authorities to alleviate the situation. The waterflow at specific points in the drainage can be determined using the waterflow meter. Using the Manning's equation, the mean water velocity can be estimated. The calculated water velocity can be compared to the actual waterflow in the drainage to detect obstructions. Another method is to calculate the peak discharge by recording the drainage size, the drainage inclination, and the drainage material type. The peak discharge at different strategic points can be compared with the calculated value.

Figure 17 shows a scenario where waterflow sensors placed at different locations namely reference point A, B and C along a drainage system. Water flows from point A to point B, and later to point C. At reference point A and B, the waterflow is estimated to be 3.25 m/s and 3.12 m/s and the actual waterflow measured is 3.26 m/s and 3.10 m/s respectively. A little deviation from the actual value can occur due to calculations inaccuracy. In case of reference point C where the deviation of the measured value is huge from the estimated value (estimated waterflow = 3.37 m/s and actual waterflow = 2.97 m/s), indicates obstructions in the waterflow passage between point B and C. In such scenarios, local authorities can be deployed to clear the obstructions blocking the water passage.

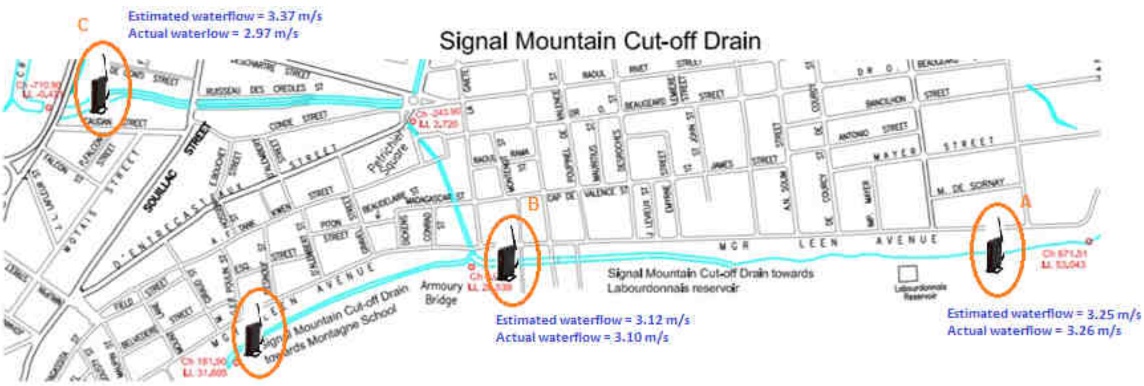



Figure 17. Waterflow meter placed at different locations to measure the waterflow rate

*6.4 Real-Time Communication and Machine Learning*

The criticality and purpose of an urban drainage monitoring system requires a 7/7 and 24-hr surveillance. The system needs to analyse real-time data to detect the overflow as soon as it happens. But it is not practical to constantly sense the environment due to battery constraint. One solution offered by Libelium (Libelium, 2012) is the combination of waspmotes to a solar power supply which delivers energy to the sensor. Figure 18 shows how Libelium sensors are connected to an external solar panel.

Figure 18. Waspmote powered by an external solar panel (Libelium, 2012)

The application of TDMA (Time Division Multiple Access) switches the sensors into sleep mode when no sensing is required (Mamalis *et al.*, 2009). On the other hand, if overflow is detected by one sensor, the system needs to activate all the sensors to detect if there are other instances of overflow. This particular behaviour can be achieved by using machine learning algorithms. Studies have shown that the Rational method, the Modified Rational method, the SCS Runoff method, the Saint-Venant equation and the Manning's formula, used for calculating the peak discharge and mean water velocity are not 100% reliable and are prone to inaccuracy. Machine learning is mostly used in complex environment where accurate mathematical models cannot be developed (Alseikh *et al.*, 2015). Consider water flowing from reference point A to point B, and then to point C along a drainage system as shown in Figure 19. Given that during heavy rainfall reference point B has high probability of overflow and once overflow occurs at reference point B, the high amount of peak discharge also causes an overflow at reference point C. Once overflow is detected at reference point B, the sensors at reference point C need also to be switched in active mode. This automatic behaviour in the system is achievable through machine learning.

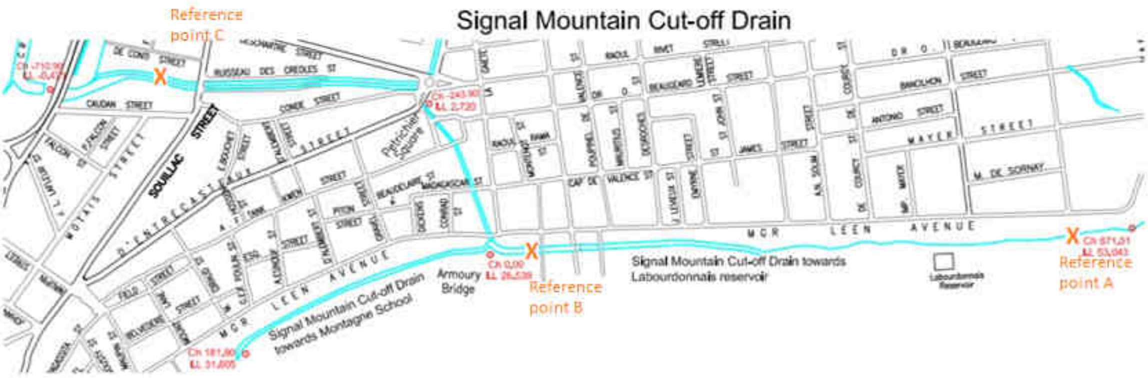



Figure 19. Detection of overflow through machine learning

It is also noteworthy that the analysis carried out in a constantly changing environment for an urban drainage monitoring system requires real-time data. The autonomous behaviour of the system through machine learning works in line with the values of the real-time data, the reason why real-time communication is important in such scenarios.

### *6.5 Topology selection and Routing Algorithms*

The topology selection in an urban drainage depends mostly on the number of nodes that will be placed, the distance between the nodes and the base station and the rate at which the data need to be transferred (Mamalis *et al.*, 2009). In the dynamic environment of urban drainage systems, cluster-based topology is one among the best option for the following reasons:

- Allows scalability: Nodes can easily be added and removed in a cluster topology with minimum alteration in the design of the wireless sensor network and routing algorithms. In case that additional nodes need to be added or damaged nodes need to be removed from the drains, this will require very less change in the deployed system. The challenging part in scaling a wireless network for urban drainage is that some nodes can be deployed distance apart from all the remaining cluster nodes outside the range for data transmission. Furthermore strategically positioned nodes cannot be easily removed as they can disrupt the functioning of the wireless sensor network.

- Less energy consumption: Data within the same cluster are combined and aggregated by the cluster head before being sent to the base station. This decreases the total energy consumption as compared to all the nodes transmitting their own data to the base station. The sensors are scheduled to swap into sleep and wake up mode to use lesser energy through slotted transmission method like TDMA (Time Division Multiple Access). But it has to be noted that nodes monitoring an urban drainage system can usually be placed apart from the cluster head or base station. These nodes will require more energy for data transmission.
- Minimum data stored by the sensor nodes: Nodes in a cluster topology have the ability to localize the route set up within the cluster. Hence, a large amount of data need not be stored in the routing tables at each sensor node located along the drains. But as the wireless network for urban drainage grows by addition of nodes, routing tables may be required to have large amount of storage capacity.
- Security of the data transmitted: Using the TDMA transmission method, data are difficult to be eavesdropped or altered by malicious devices as they need to know the exact timing of the transmission within the cluster. Furthermore, transmission between cluster heads (more powerful node) and base station can be encrypted for a more secure transmission. Manipulated data received by the base station can consequently display inaccurate results triggering unwanted activities from the local authorities.

LEACH (Low Energy Adaptive Clustering Hierarchy) is one of the most appropriate routing algorithms for this type of scenario as it focuses more on the principle of energy conservation and hence prolongs the lifespan of the wireless network. The selection of cluster head can be done depending on the residual energy of the sensor nodes (Quing and Tixin, 2014). LEACH algorithm allows addition and removal of nodes without interrupting the usual function of the network system. It also provides numerous routing paths, is highly reliable, has low probability of node failure, and encounters very less routing congestions. There are numerous types of LEACH routing algorithms such as LEACH, LEACHC, TLEACH and LEACH with Responsibility Transmission. The selection can be done based on the characteristics required with regards to the network type (Mamalis *et al.,* 2009). The challenge remains in the selection approach for the appropriate LEACH algorithm and the parameterizations of the routing algorithm. Communication protocols between the nodes should be correctly chosen and proper calculation of the optimal bandwidth needs to be carried out for non-erroneous transmission of data.

## 7. Conclusion

Urban drainage systems have been helping mankind in its daily activities since the start of civilization. Waste waster evacuation prevents flood and proliferation of diseases. However, urban drainage systems have evolved very little over the years. Population is growing arithmetically in urban regions and the climatic changes have made our weather forecasting less and less precise. With localized high rainfall around the world, urban regions are not safe from floods. Our drainage systems that are design and constructed on historical based methods and numerous assumptions, no longer serves the purpose of evacuating water.

Existing mathematical methods namely the Rational method, the Modified Rational method, the SCS Runoff method, the Saint-Venant equations and the Manning's formula output estimated values. Initial abstraction, runoff coefficient, rainfall intensity, ground absorption, potential maximum retention and Manning's roughness coefficient cannot be calculated or measured precisely. The inaccuracy in the calculated value varies from soil absorption, precipitation rate, drainage size and drainage construction. An analysis of the wireless sensors capability and efficiency to capture water level and water flow is carried out in this paper. It is noted that numerous sensors are now available on the market that can be used to monitor drains. In addition, the sensors can be connected to weather monitoring stations and be powered by solar batteries. A number of existing monitoring systems have been assessed and it can be deduced that the implemented systems are customized as per the need of the output data and sensing environment. A number of challenges that need to be considered for the monitoring of an urban drainage through wireless sensors are discussed in this paper. Practical and feasible solutions are proposed to resolve the potential problems. The capability of powerful sensors, newly developed algorithms and enhanced technologies are combined with machine learning, optimal topology and routing algorithms for more reliable and efficient means to detect drainage overflow.

It can be concluded that appropriate urban drainage monitoring systems may be developed using simple and readily available water level and water-flow sensors. Developing an urban drainage monitoring system whose behaviour can be customized through machine learning can be advantageous in triggering the required action and in increasing the lifespan of the system. Future works need to be carried out on the routing algorithm and topology of a wireless sensor network for an urban drainage monitoring system.

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