Improving city infrastructure resilience capacity:
water-supply network case study

O. Jukić, I. Heđi, I. Špeh
Virovitica College, Virovitica, Republic of Croatia
{oliver.jukic | ivan.heđi | ivan.speh}@vsmti.hr

Abstract - Main goal of research in this paper is to improve city infrastructure resilience capacity as well as management process of water supply network. Namely, water supply network is located over the wide city area, typically managed by company established for that purpose owned by city government. Water supply network is very important part of the city infrastructure. Hence, it is necessary to ensure high-quality and reliable water supply network management process. Our research is focused on mapping of telecommunications network management principles into water supply network management. Complete network view is graphically and geographically oriented using GPS based network elements coordinates. Real-time network control and management is based on network inventory management process which is presented in our previous work. Data from the real network are included in network management process using telemetry techniques and will enhance network management process. Finally, network model and relevant real-time data are integrated into the complete system that will cover all city infrastructure, acting as infrastructure data interchange portal usable especially in the case of disasters such as flooding, earthquakes, volcanos, etc. Indirectly, citizens will communicate with this platform through different users or services using telecommunications infrastructure.

I. INTRODUCTION

A. Water supply network

Every water supply network is located over the wide city area, typically managed by company established for that purpose owned by city government. Water supply network is very important part of the city infrastructure. In network theory, there are four general classes of networks: technological networks, social networks, information networks and biological networks. The division into classes is a useful one, since networks in the same class are often treated using similar techniques, ideas and algorithms [1]. Both telecommunication and water supply network belong to the class of technological networks. In water supply network almost all network elements are invisible, located in the ground. In most cases, network elements are not accessible through any communication infrastructure, and they are “software-free” elements. Hence, there is no possibility to implement self-detection or auto-discovery features. Hence, it is rather important to implement and maintain network configuration database. Water supply network operators usually have “database” as a collection of different type documents describing network, even in the electronic form. However, that is not enough for maintenance and management activities. There is very strong need for information system for network configuration management, which we call “inventory” management (in water supply network we use term “network inventory” for all elements building water supply network). As a first step in our research we have focused on related work and developing of our own water supply inventory management system [2].

B. Inventory management system architecture

Inventory management system architecture is shown on figure 1.

![Inventory management system architecture](image)

Figure 1. Inventory management system architecture

The system was developed and launched during the project “Knowledge-based water supply management” sponsored by company “Komrad d.o.o.”, Slatina. System core is located at database layer. There are three main databases: network inventory database, repairing action database and real-time performance database. Central database in the context of network inventory system is network inventory database. It can be assumed as configuration database. Since there are no auto-discovery or self-detection features in a “software-free” network,
network inventory data must be imported into the database through graphical network presentation interface. Data collection process includes consolidation of all possible sources within the company, such as: network schemas, network descriptions, project plans, repairing logs, internal human knowledge, informal notes etc. Generally, there are two types of network elements: basic elements, such as valves or pipes, that cannot be divided into the smaller parts; compound elements, such as manhole, are compound of number of basic elements. GPS coordinates are a very important part of network inventory data model, since they allow network presentation on any GPS supporting platform [2]. Main functions of mediation layer are:

- data collection from water-supply network
- unification of all data formats
- aggregation of collected data on low level, preparing it for storage in real-time performance data warehouse

All data are collected by specific applications called access modules. Every access module uses specific techniques and performs specific actions in order to obtain data from the water-supply network. For instance, data can be collected through any kind of communication protocol (usually using GPRS for data transport), from existing databases or industrial measurement solutions [6]. Topology for collecting real-time data is shown on figure 2.

![Figure 2. Topology of communication for collecting real-time data](image)

Network presentation GUI is web interface located on the top of database layer. At presentation layer there is performance monitoring module. This is graphical interface which is connected to real-time performance data database and reading last measurement value for each node which consists of slave flow measuring module and serves as “performance cockpit”. Basis for this graphical interface is Network inventory data presentation on GPS supporting platform (Figure 3.).

![Figure 3. Network inventory data presentation on GPS supporting platform](image)

C. Related work

Vienna Waterwork’s approach to network maintenance and rehabilitation is described in [3]. Network information system of Vienna Waterwork is briefly presented. System is primarily used to provide assistance platform for planning process. For predicting pipe failures the proportional hazards model (PHM) is used.

GIS-based water supply information system for an urban area is described in [4]. The basic aim of that water supply information system is to serve as a decision support tool for Waterwork’s management by helping maintain records of leaks and repairs.

Both systems are focused on inventory management, but currently without GPS coordinates. Real-time data integration is also not considered.

In [5] system using telemetry for obtaining real-time data from water-supply network is described. However, all data are propagated to SCADA application; inventory management is not considered.

All facts mentioned above have encouraged us to continue research and development activities leading to the integration of real-time collected data with network inventory system based on GPS coordinates.

II. PLATFORM TO IMPROVE CITY INFRASTRUCTURE RESILIENCE CAPACITY

A. Water supply area

In the water-supply network covered by our inventory management system, water is pumped into the two so-called zones: Low zone covers city area. There is clean water tank above the city - unused water from distribution network is pumped to this clean water tank. If necessary (for instance, if pumps are out of order, or capacity provided is less than capacity needed), water from tank is distributed by gravity to the city. High zone covers neighboring municipalities, with couple of alternative drinking water sources with limited capacity. Both high and low zone have its own distribution network and also its “access” network where customers are
connected to the network. All data about network inventory are handled by information system described in previous section, providing real-time data collection, therefore enabling not only inventory data collection, storage and visualization, but also real-time network management.

B. Water supply network general architecture

The general water flow in the architectural system shown in Figure 4 is defined as follows:
1. Water is extracted from the sources under the earth. Physical and chemical processing is done.
2. Water is stored into the clean water tanks (3 tanks).
3. Pumps are pumping clean water from the tanks in 2 directions called “Low” and “High” zone. “High” zone is actually city while “Low” zone are municipalities around. Actually, this is the point where water-flow enters the water distribution network.
4. Main pipeline to “high” zone is couple of kilometers length. There is the possibility to waste larger amount of water in short time period, because of huge diameter.
5. Water is distributed all over the city. Unused water is pumped to clean water tank located above the city.
6. If necessary (for instance, if pumps are out of order, or capacity provided is less then capacity needed), water from tank is distributed by gravity to the city.
7. Main pipeline to “low” zone is linking number of municipalities. There is the possibility to waste larger amount of water there, because of huge diameter also.
8. Every municipality has its own distribution network.
9. There are several small secondary sources of water located in municipalities. This water is injected in the general pipeline.
10. Pipeline for “low” zone forms a loop returning water to the water processing plant.
11. Whole process is monitored by Network operating center.

C. Network operating center

The network operating center is located at the “Water processing plant”. Company is always guaranteeing personnel in these premises.

The General network operating center architecture is shown in Figure 5.

The network monitoring system includes:
1. Number of PLC controllers collect data from the plant. These data are mostly related to water processing, but there are number of parameters related to water distribution. For instance:
   - Pressure of water flow toward the “Low” or “High” zone
   - Flow of water stream toward the “Low” or “High” zone
   - Current amount of water in clean water tanks
   - Current pump status
   - Current pump power
2. Data from OPC controllers are stored in OPC (Ole for Process Control) server. Data are obtainable by any OPC client (standardized access).
3. The SCADA application, actually it is “RSView”, OPC client. There are number of graphical presentations of water processing with integrated real-time data measured by PLC controllers.
4. Network inventory management system is located in the City of Slatina (web application with MSSQL server database).
5. Data from OPC server can be integrated in Inventory management system also, allowing tracking of important KPIs
6. Data from sensors located in network are integrated into Inventory management system also.

D. Central IT platform

Generally Central IT platform is used to collect whole relevant data from different sources such as water supply network operating center, electricity network operating center, gas transmission network operating center, telecommunication network operating center, citizens, 112 service and so on in emergency situation like flooding or some other type of disaster and triggers some relevant actions such as crisis emergency alerting, crisis management actions etc. Currently in test phase we collect relevant data which are connected to distribution of clean water which is very important when flood occur. Next phase of this research is to include all other relevant source and get complete central IT platform to improve city infrastructure resilience capacity.

One potential scenario of using that platform is when floods occur. This platform will be used (not exclusively) by (see Figure 6.): first responders such as police officers, firefighters, emergency medical technicians (EMT), infrastructure operators (water supply, electricity, gas transmission and telecommunications network operators),
Users from 1-5 will approach platform in both directions through a platform front-end (I1). Term “both directions” means they will be able to trigger some actions, or to receive guidelines, triggers, data etc. from platform. Some data are collected in permanent regime, while other are collected on demand (when something is “triggered” from the environment). Citizens will approach platform directly (I1) or indirectly. It is expected that more citizens from urban area will approach platform directly. Citizens from rural area probably will use another channels to send/obtain relevant information related to current disaster situation. Indirectly, citizens will communicate with platform through different users/services using telecommunications infrastructure: by contacting (phone, SMS, e-mail,...) to city council (Ii), by contacting (phone, SMS, e-mail,...) to service #112 (Ii), by contacting (phone, SMS, e-mail,...) to local electronic media and by receiving information from media (Ij), by contacting (phone, SMS, e-mail,..., first responders and/or infrastructure operators directly (Ij). One possible scenario when floods occur are shown on Figure 7.

The workflow acts as follows: flooding alert is sent from citizens via different channels to city council, Service 112 or Central IT platform. Flooding alert is received and forwarded from the city council and Service 112 to the Central IT platform. Central IT platform performs internal processing, based on data collected on permanent regime, data from other sources, internal algorithms, rules etc. Resilience management guidelines (RMG) are launched and delivered/published to all platform users. For instance, Citizens can approach RMG by web or mobile application. According to RMG received, Water Supply Network Company will perform specific actions on water supply distribution network. For instance: detect areas where clean water distribution is disrupted increase/decrease pump power, switch on/off specific valves in order to cause re-routing of water-flow, fill up clean water tanks, generate specific alerts to citizens and other. At the same time, city council and firefighters will organize clean water provisioning to the areas where water clearance is disturbed. Actions mentioned above are coordinated. Local electronic media will inform citizens about current situation (e.g. public city alarm – siren).

E. Legislation at the area of emergency management

System of protection and rescue of citizens, material and other goods in catastrophes and big accidents, way of controlling, handling and coordinating, tasks and constitutions of bodies for administration, way of alarming and informing in activities of protection and rescue in Republic of Croatia is regulated by the Law on Protection and Rescue. In catastrophes and big accidents district head (city council), mayor and district prefect directly command operative forces of protection and rescue of units from local and regional government. Each person has right to complete and timely information about all threats from the beginning of catastrophes and possibilities, ways, measures and activities of protection and rescue and if they notice threat from beginning of accident, big accident or catastrophes or its beginning, it is their duty to inform Service 112 without any delay, using the most convenient way and the fastest way of information transfer [7]. According to the Law on Critical Infrastructures, national critical infrastructures are systems, networks and objects of national importance whose disruption of functioning or disruption of goods or services supply can have serious consequences on national security, health and lives of people, possessions and environment security and economic stability and undisrupted functioning of government (water supply network, telecommunication network, electricity supply network etc.) [8]. By-law about standard operative procedures regulates the way of common action of operative forces (standard operative procedure) and Service 112, procedure for transfer of all available information connected to the emergency situation, accident or catastrophe after receiving information through number 112, procedure of processing and forwarding received information to operative forces and other participants of protection and rescue using most suitable and the fastest way of information transfer. So, there are some possibilities to implement Central IT platform to Service 112.
III. CONCLUSION

In this paper we have presented information system which is used to improve city infrastructure resilience capacity and it is based on inventory management system in water-supply network. Based on existing experience in telecommunications management area, we have compared basic aspects of management in water-supply and telecommunication networks. Encouraged by the results, we have developed inventory management system for water-supply network. Some of system components are still subject of research efforts; it will be subject of future work and will be presented in future papers. Main goal of research in this paper is to improve city infrastructure resilience capacity as well as management process of water supply network. Namely, water supply network is located over the wide city area, typically managed by company established for that purpose owned by city government. Water supply network is very important part of the city infrastructure. Hence, it is necessary to ensure high-quality and reliable water supply network management process. Our research is focused on mapping of telecommunications network management principles into water supply network management. Complete network view is graphically and geographically oriented using GPS based network elements coordinates. Real-time network control and management is based on network inventory management system which is presented in our previous work. Data from the real network are included in network management process using telemetry techniques and will enhance network management process. Finally, network model and relevant real-time data are integrated into the complete system that will cover all city infrastructure, acting as infrastructure data interchange portal usable especially in the case of disasters such as flooding, earthquakes, volcanos, etc. Indirectly, citizens will communicate with this platform through different users or services using telecommunications infrastructure.

REFERENCES