Telecom Traffic Characterization & Quality of Service in a Smart City: Municipal Heritage Management Service

Zhuhan Jiang[1], Angel Gomez-Sacristan[2], Miguel A. Rodriguez-Hernandez[3]

[1] Beijing University of Posts and Telecommunication, 100876 Beijing, China
z.jiang@se14.qmul.ac.uk
[2] Instituto ITACA, Universitat Politècnica de València, Camino de Vera s/n, 46022, Valencia, Spain
agomez@dcom.upv.es
[3] Instituto ITACA, Universitat Politècnica de València, Camino de Vera s/n, 46022, Valencia, Spain
marodrig@upvnet.upv.es

Abstract. This paper aims to define characterization of telecom traffic sources in intelligent municipal heritage management service inside smart sustainable city (SSC) and to find out a proper quality of service (QoS) mechanism for this communication network using Valencia City as background. Four traffic heterogenous sources were defined according to real-life requirements and datasheet of sensors suitable. Different simulation has been made to find proper CIR (Committed Information Rate) and PIR (Peak Information Rate) values for this network. Network's performance was checked through its packet loss, throughput, delay and jitter. As the result, we defined minimum values for PIR and CIR, and thus traffic telecom costs.

1 Introduction

Smart sustainable city (SSC) is a kind of city combing devices able to utilize information and communication technology (ICT) with the existing infrastructures (such as building and lights) in a city [1]. By using ICTs, SSC is capable to converge all systems and able to control all resources in this city. Therefore, the consequence that saving cost and energy can be achieved.

This paper is based on an existing network structure and simulator, aiming to solve a problem that heterogeneous sensors in the existing telecommunication networks are needed to be implemented. In case of the study, intelligent heritage management, consisting of multiple sensors, is included in municipality network that is going to be analyzed. The intelligent heritage management is a kind of service protecting heritages from deterioration causes that will damage the durability of art work [2]. Deterioration causes are those physical factors and human-made destructions. For example, artworks can be influenced by surrounding environment agents such as temperature, humidity, ultraviolet and chemical agents (e.g., SO_2, O_3, NO, etc.) [3]. Therefore, to protect heritages from those destructive agents all the time, an intelligent system is

C.Fernandez-Llatas and M.Guillen (Ed.):
Workshop on Innovation on
Information and Communication Technologies
(ITACA-WIICT 2018)

ISBN 978-84-09-07373-3

required to provide art heritages with real-time monitoring and recording of historical data.

The objective of this paper is to simulate the behavior of municipal communication network including intelligent heritage management, analyzing the bandwidth consumed, delay, packet loss, etc. The work included is an application of Internet-of-things (IoT) allowing heterogeneous sensors to be applied together [4]. The goal is to find how to ensure an adequate quality of service (QoS) in a network of heterogenous devices.

In the scenario of smart city shown in Fig1, there are city council internal network, MPLS network and city platform servers. Inside the city council internal network, there are traffic sources and output trunk. The sources refer to heterogenous sources included in the intelligent municipal heritage management service, and the output link is responsible for collecting all generated data and transferring them forward to outside network. MPLS network is multiprotocol packet label switching network that is used between hosts and servers [5], transmitting packets from the city council internal network to corresponding remote servers. City platform servers are controllers receiving all data from sources and monitoring services.

The network also has QoS mechanism to ensure that important information is not delayed too much or dropped in the network, making sure the network is operating under a high efficiency and quality. QoS mechanism includes five steps: classification, marking, policing, queueing and scheduling [6]. Classifications used are multimedia, gold and silver that defined based on a Macrolan of smart hospital [7]. The policer used is two rates Three Color Meters (trTCM).

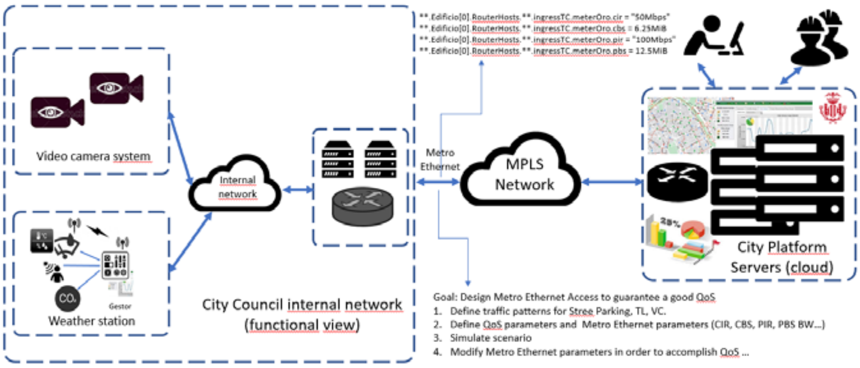

Fig. 1. Scenario of smart city in functional view

This paper is written in five parts: Section 2 introduces the simulation tool OMNET++; Section 3 introduces the intelligent municipal heritage service and heterogenous sources included inside; Section 4 shows the results of simulations implementing smart city network; Section 5 concludes the work and lists further work.

2 OMNET++ Introduction

OMNET++ is a network simulator programmed and compiled in C++, based on which we can create and test telecommunication network simulations with many different structures and configurations. This tool has a huge number of basic libraries and it is extensive enough to satisfy different requirements, we can use it to establish many kinds of networks. For easy operations and designs, OMNET++ also provides an Eclipse-based IDE, the network is described in high-level language [8].

2.1 Components of one simulation

In OMNET++ simulator, one simulation consists of five main parts: network description file (.ned, which describe the structure of this network), network definition file (.cc, which define the communication mode), message definition file (.msg), simulation kernel library and user interface library(.lib/ .a) and profile (.ini).
Among them, NED and INI file are main parts of one simulation that we need to define: NED file describes the structure of network including modules and connections. There can be multiple NED files in one simulation; INI file defines the configuration of one simulation, such as defining communication rules and matching sources with destinations. Besides, we use XML file to add complementation to one simulation.

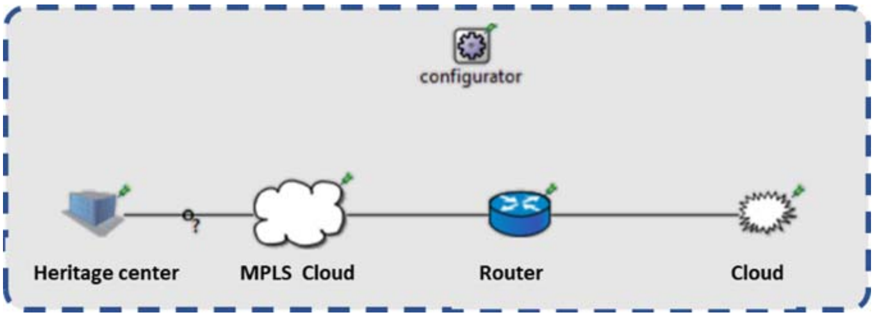

Fig. 2. NED file of the simulation defining the topology of smart city communication network implemented in OMNET++

2.2 Run the Simulation

After defining all three kinds of files, we can start the simulation by running the "ini" file by clicking "Run As OMNeT++ Simulation" button. Then the window of simulation is generated, we can click on the "run" or "express" button to start it. After one simulation arrives the time limitation, it will finish and generate results in result list. Then any analyzation and evaluation based on results can be applied.

3 Intelligent Municipal Heritage Management

In order to protect heritage from deterioration causes, three kinds of sensors and a video surveillance system are concluded inside. Video surveillance system is applied to monitor surrounding situation, in case that someone may damage art work. Sensors are temperature and humidity sensor, lighting and ultraviolet sensor and gas sensor, used to detect physical agents around art work and provide real-time data of physical agents to city council. In this section, traffic sources characterizations are defined.

3.1 General Characterization of Video and Data Sources

Traffic sources can be divided into three classes in content: voice, video and data sources. Voice and video sources belong to human type communication, having active and inactive time. Data sources belong to machine type communication, having burst intervals and huge number of sources. In definition of one source, there are four parts: start time, class of service, quality or data size and profile. Start time is the time when this service begins to transmit information, commonly a random variable. Class of service is the priority of one source (multimedia, gold and silver). Quality or data size define the packet size. Profile stores the configuration of one source, different kinds of source have different parameters included. Tables 1 and 2 show the general model of data and video source.

Table 1. General Characterization of Data Source

Parameter	Type	Description
Text resource size	Data size	Size of each text packet (in bytes)
Image resource size		Size of each image packet (in bytes)
Number of text resource		Number of text resource in the file
Number of image resource		Number of image resource in the file
Number of packets	Profile	Number of packets in one session
Send interval		Time between two packets
Number of bursts		Number of sessions in total
Burst interval		Time between two sessions

Table 2. General Characterization of Video Source

Parameter	Type	Description
Res X	Video Quality	Frame width (in pixels)
Res Y		Frame height (in pixels)
Duration	Profile	Duration of a video (minutes)
Time inactive		Time when no video generated (minutes)
Movement		The level of movement in a video (1 to 4)
Frame per second(fps)		Number of frames in one second

3.2 Video sources definition

In order to define video sources of video surveillance system, we compared several cameras according to requirements of this service at first to find the most proper terminal for this system. Table 3 shows the comparison.

From the comparison, we found everyone has its pros and cons. But, according to the importance of each function, we chose the third one, “TV-IP450P”. The reasons are: 1) The motion detection is one of the most important function for surveillance. 2) The requirements for shutter speed is between 1/1 – 1/1,000s, the second one’s shutter speed is too much. After the selection, we defined video sources characterization from its data sheet and real-life condition, which is shown in Table 4.

Table 3. Comparison of four cameras. “IP2M-846EB”[9] and “IP2M-850E”[10] come from Amcrest company, “TV-IP450P”[11] and “TV-IP450PI”[12] come from TRENDnet company.

Parameter	IP2M-846EB	IP2M-850E	TV-IP450P	TV-IP450PI
Minimum illumination (Lux)	Color: 0.05 B/W: 0.005	Color: 0.05 B/W: 0.005	Color: 0.05 B/W: 0.01	Color: 0.05 B/W: 0.01
Shutter speed (s)	1/1–1/30000	1/3–1/30000	1/1–1/10000	1/1–1/10000
Zoom	Digital: 16x Optical: 4x	Digital: 16x Optical: 20x	Digital: 16x Optical: 20x	Digital: 16x Optical: 20x
Viewing angle	H:116.5-34.5° V: N/A	H: 54.1-3.2° V: N/A	H: 54° V: N/A	H: 54° V: N/A
Focal length(mm)	2.7– 11mm	4.7– 94mm	4.7– 94mm	4.7 – 94mm
Max Aperture	F 1.6 – 2.8	F 1.4 – 2.6	F1.4 – 3.5	F1.4 – 3.5
Rotation angle/ inclination	Pan: 0 – 360° Tilt: 0 – 90°	Pan:0 – 360° Tilt: -15–90°	Pan: 0–360° Tilt: -5– 90°	Pan: 0 – 360° Tilt: -5 – 90°
Day/ Night	Yes	Yes	Yes	Yes
Resolution	1280x720	1280x720	1280x960	1280x960
Video encoding	H.264/MJPEG	H.264/MJPEG	H.264/MJPEG	H.264/MJPEG
Max frame rate	30fps	30fps	30fps	30fps
Motion detection	N/A	Yes	Yes	N/A
Alarm handling	2/1 channel in/out	2/1 channel in/out	External alarm	External alarm
Audio detection	Yes	Yes	Yes	Yes
Microphone input	N/A	N/A	External	External
Network Port	RJ-45	RJ-45	100Base-T	100Base-T

Table 4. Characterization of Video Source in video surveillance system

Video Surveillance					
Number		10			
Start time		Uniform(0s,900s)			
Class of service		Gold			
Video Profile	Duration	Type: Exponential	Mean: 5	Min: 3	Max: 7
	Time Inactive	Type: Exponential	Mean: 15	Min: 10	Max: 20
	Movement	2			
	fps	25			
Video Quality		1280 x 720			

3.3 Data sources definition

Similar as video sources, three different sensors should be selected firstly to define corresponding characterizations. Due to their corresponding requirements, we select several candidates and finally defined three proper sensors.

For temperature and humidity, we select one sensor that can detect both of them. After comparing range of measurements and their accuracy with requirements, we select "Humidity and Temperature Transmitter EE33-M"[13] finally. Because this sensor has higher accuracy than requirements and larger measuring range. For lighting and ultraviolet, sensor should capable to detect ambient brightness and sunlight strength on the surface. Due to those needs, we choose "UVB+UVA Sensor PMA1107"[14] as corresponding sensor. For gas sensor, we chose the one that can measure NO_2, O_3, CO and SO_2 of environment and the particle PM2.5 and PM10 in the environment [15]. Because this sensor should be used indoor to protect heritage, we chose the one having highest accuracy and bigger range than others. Table 5 show characterizations of data source from gas sensor, the other sensors are modulated in a similar way.

Table 5. Characterization of data source from gas sensor

Number		8
Start Time		Uniform(0s,180s)
Class of Service		Silver
Data Profile	numPackets	1
	SendInterval	1
	numBursts	1
	burstInterval	3600s
Data Size	textResourceSize	20 Bytes
	numResources	4

4 Simulations and results

This section shows the results of simulations. This section is divided into two parts. In the first part, we simulate this service to find our proper value of CIR and PIR. Then we simulated to find the proper bandwidth that should be assigned to this network in output link.

4.1 Test CIR and PIR

Table 6. QoS mechanism parameters and corresponding results for video source (gold class)

	CIR (Mbps)	CBS (MiB)	PIR (Mbps)	PBS (MiB)	Packet loss
CIR<PIR<Max throughput	10	1.25	20	2.5	140520
CIR<Max throughput<PIR	20	2.5	30	3.75	0
Max throughput<CIR<PIR	50	6.25	60	7.5	0

For the four sources included in this service, we firstly classified them based on their characterization. Video source is classified into gold class for its high time sensibility. Data source is classified into silver class for its lower importance and time sensibility. Therefore, we test CIR and PIR of gold and silver class communications. CIR is the guaranteed communication speed for important data in one connection, PIR is the limitation of one connection to define the maximal speed. Tests are divided into three conditions:

1) CIR < PIR < maximal throughput,
2) CIR < maximal throughput < PIR,
3) maximal throughput < CIR < PIR.

Table 6 and Table 7 show the parameters we assigned for two classes.

Table 7. QoS mechanism parameters and corresponding results for data source (silver class)

No.	Condition	CIR (kbps)	CBS (KiB)	PIR (kbps)	PBS (KiB)	Packet loss
1	CIR<PIR<Max throughput	0.4	0.05	0.8	0.1	90
2	CIR<Max throughput<PIR	0.8	0.1	2	0.25	0
3	Max throughput<CIR<PIR	20	2.5	30	3.75	0

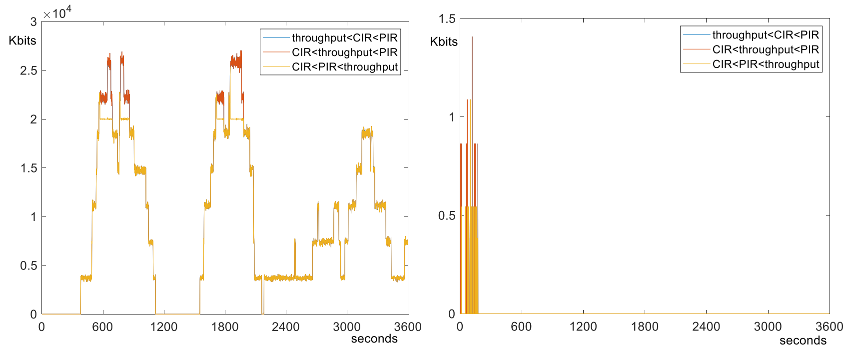

Fig. 3 Throughput of 10 video (*left, kbits/sec*) and 37 data sources (*right, kbits/sec, 21 temperature and humidity sensors, 8 lighting and ultraviolet sensor, 8 gas sensor*) under three conditions (*Blue line for condition 3, orange line for condition 2, yellow line for condition 1*).

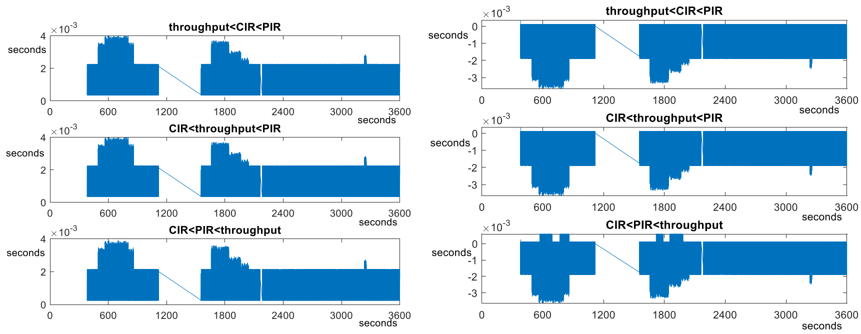

Fig. 4 Delay (*left, sec/sec*) and jitter (*right, sec/sec*) of 10 video sources under three conditions. (*Top one for condition 3, middle one for condition 2, bottom one for condition 1*).

After simulating each condition for 1 hour, we got results shown in figure 3, figure 4 and figure 5.

Because three data sensors have similar characterization, we showed result of temperature and humidity sensor as an example of data source. From figure 3, the throughput of 20 video sources is from about 0 Mbps to 32 Mbps, and the throughput of data sources generated from temperature and humidity sensor is around 1.1 Kbps. For both data and video sources, the throughput under condition 1 is obviously limited under 20Mbps, that difference happened when throughput exceeds PIR value and caused huge packet losses.

The throughput under condition 2 is not influenced so much by low CIR because the packet sizes and throughput of this service are not big enough to cause obvious distance. From figure 4, the delay and jitter of video source under condition 2 is slightly higher than condition 3 but the delay and jitter under condition 1 is obviously lower than other two conditions.

That showed that many packets are dropped directly instead of waiting in the queue, causing lower delay and jitter. The delay and jitter of data source shown in figure 5 are in a similar result.

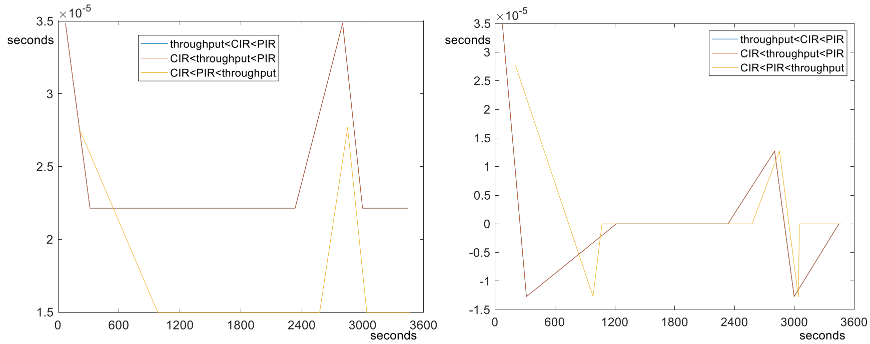

Fig. 5 Delay (*middle, sec/20s*) and jitter (*right, sec/20s*) of 21 temperature and humidity sources under three conditions. (*Blue line for condition 3, orange line for condition 2, yellow line for condition 1*).

4.2 Test total bandwidth

Three levels were tested for this simulation, 10M, 100M and 1G. The result of three two-hour-simulations are shown in figure 6, figure 7 and figure 8. Temperature and humidity sensor was still used as the example of data source.

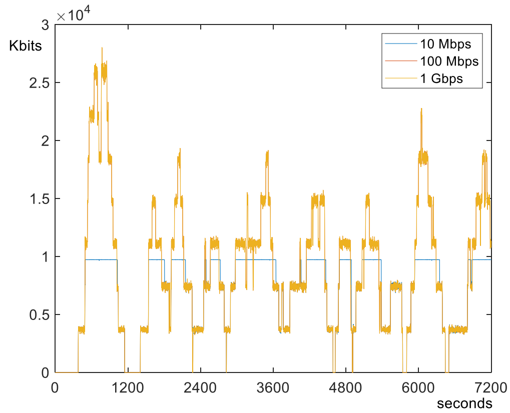

Fig. 6 Throughput (*kbits/sec*) in output link (*10 video sources and 37 data sources*) under three different bandwidths (*Blue line is for 10M, orange line is for 100M, yellow line is for 1G*).

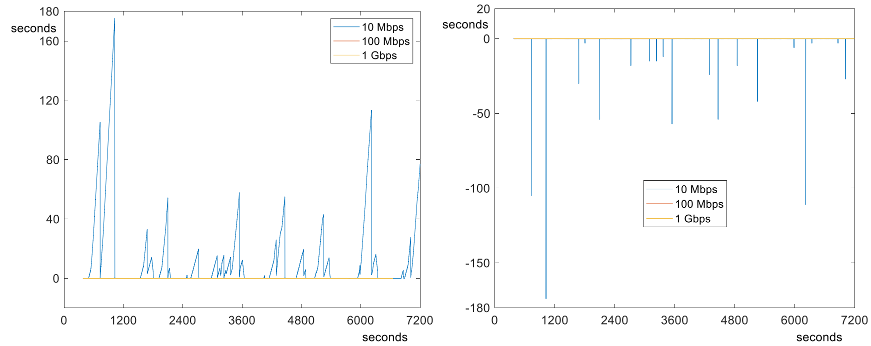

Fig. 7 Delay (*left, sec/sec*) and jitter (*right, sec/sec*) of 10 video sources under three bandwidths (*Blue line is for 10M, orange line is for 100M, yellow line is for 1G*).

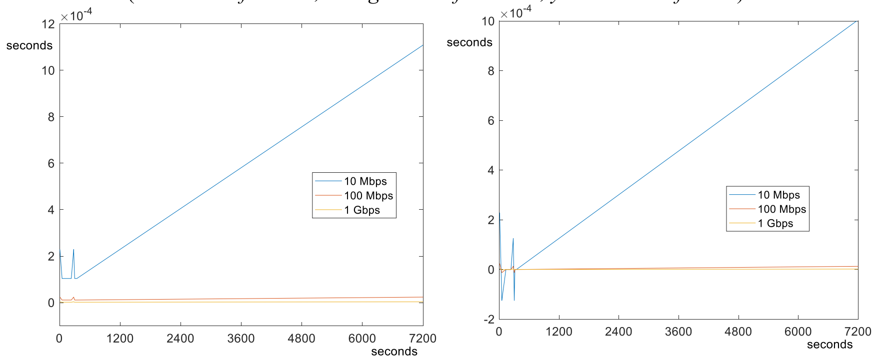

Fig. 8 Delay (*left, sec/ 2s*) and jitter (*left, sec/ 2s*) of 21 temperature and humidity sensor under three conditions (*Blue line is for 10M, orange line is for 100M, yellow line is for 1G*).

The results showed that the throughput under 10M is obviously lower than other two bandwidths, causing 1,205,120 packets lost. And the delay of both video and data sources are also larger than other two bandwidths. Due to large throughput of video sources, the bandwidth assigned must larger than 32Mbps. Therefore, 10M is definitely not large enough.

For 100M and 1G, there are almost no differences in throughput of video and data sources, delay and jitter of video source, but small differences in delay and jitter part for data sources. However, that small difference doesn't influence normal communication for sources in lowest priority. Because that bandwidth is very important source, 100M is the better choice for this service than 1G in order to save bandwidth.

5 Conclusions and Further Work

From all tests of simulation, following conclusions about QoS mechanism and bandwidths were achieved:

1. The simulation tools provide a flexible and economical mechanism to evaluate the network impact of projects that generate heterogeneous traffic with finite sources.
2. Lower CIR or PIR limits the throughput and cause delay, jitter and packet losses.
3. It is necessary to perform an iterative process to get calculate the appropriate parameters of bandwidth, CIR & PIR and in this way to minimize the costs of the necessary communications for this project.

As future lines of work, it may be of interest to evaluate the impact on the municipal network of the implementation of new projects that share the available bandwidth and the resulting aggregate traffic. Besides, after intelligent municipal heritage management system has been established in the future, more accurate and exact real data can be achieved to test the behavior and performance of this network.

References

1. ITU-T Y.4250 series. Smart sustainable cities – Overview of smart sustainable cities infrastructure. ITU-T Y-series Recommendations – Supplement 30 (2016)
2. Mesas-Carrascosa, F., Santano, D., Larriva, J., Cordero, R., Fernández, R. and García-Ferrer, A. (2016). Monitoring Heritage Buildings with Open Source Hardware Sensors: A Case Study of the Mosque-Cathedral of Córdoba. *Sensors 2016*, 16, 1620
3. Garcia Diego, F., Esteban, B., Merello, P. (2015). Design of a Hybrid (Wired/Wireless) Acquisition Data System for Monitoring of Cultural Heritage Physical Parameters in Smart Cites. *Sensors*. pp. 7246-7266.
4. Gribaudo, M., Lacono, M. And Levis, A. (2017). An IoT-based monitoring approach for cultural heritage sites: The Matera case. *Wiley*. 2017;29;e4153. John Wiley & Sons, Ltd.
5. Heron, G., Martini, L. (2008). 'MPLS'. In: Kasim, A. (eds.). *Delivering carrier ethernet*. The McGraw-Hill Companies. pp. 421-467.
6. Evans, J., Filsfils, C. (2007). 'Data Plane QOS Mechanisms', pp. 99-100, In: *Deploying IP and MPLS QOS for multiservice Networks*. USA: Elsevier Inc.
7. Gomez-Sacristan, A., Rodriguez-Hernandez, M. and Sempere, V. (2015). Evaluation of Quality of Service in Smart-Hospital Communications. *Journal of Medical Imaging and Health informatics*. 5, pp. 1-6
8. OMNET++, *What is OMNET++?* [online] Available from: https://omnetpp.org/intro [Accessed 20 January 2018]
9. Amcrest, *Amcrest ProHD Indoor PTZ (4x Optical Zoom) 1080P POE IP Camera, 98ft Night Vision, Pan/Tilt/4x Motorized Zoom, Wide 116° Viewing Angle, 2-Megapixel (1920TVL), Sentinel, IP2M-846E (Black)* [online] Available from: https://amcrest.com/amcrest-prohd-indoor-2-megapixel-poe-ptz-dome-ip-security-camera-4x-optical-zoom-wide-116-viewing-angle-2mp-1920tvl-ip2m-846e-black.html [Accessed 2 March 2018]
10. Amcrest, *Amcrest ProHD PTZ (20x Optical Zoom) Outdoor POE IP Camera Speed Dome 1080P, 328ft Night Vision, POE+ (802.3at) - IP66 Weatherproof, Pan/Tilt/20x Motorized Zoom, 2-Megapixel (1920TVL), Goliath IP2M-850E (Black)* [online] Available from: https://amcrest.com/amcrest-prohd-outdoor-2-megapixel-poe-ptz-ir-speed-dome-ip66-

weatherproof-remnote-360-field-of-view-2mp-1920tvl-ip2m-850e-black.html [Accessed 2 March 2018]

11. Trendnet, *Outdoor 1.3 MP HD PoE+ Speed Dome Network Camera* [online] Available from: http://www.trendnet.com/products/proddetail?prod=220_TV-IP450P [Accessed from 3 March 2018]
12. Trendnet, *Outdoor 1.3 MP HD PoE IR Speed Dome Network Camera* [online] Available from:http://www.trendnet.com/products/proddetail?prod=105_TV-IP450PI#tabs-solution02 [Accessed from 3 March 2018]
13. E+E Elektronik, *EE33-M Humidity and Temperature Transmitter for High-end Meteorological Applications* [online] Available from: https://www.epluse.com/en/products/humidity-instruments/industrial-humidity-transmitters/ee33-m/ [Accessed from 4 March 2018]
14. Solar light, *Model PMA1107 Analog Non-Weighted UVA+B Sensor* [online] Available from: https://solarlight.com/product/uvauvbsensorpma1107/
15. Vaisala, *Air Quality Transmitter AQT400 Series* [online] Available from: https://www.vaisala.com/sites/default/files/documents/AQT400-Series-Datasheet-B211581EN.pdf