ISS-EWATUS

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ICT - Information and Communication Technologies

D2.2 The installation of sensors at household level

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Task Leader: Katarzyna Samborska (IETU)

Authors: Katarzyna Samborska (IETU),
Rafał Ulańczyk (IETU),
Shuang-Hua Yang (LU),
ChrysiLaspidou (CERTH),
Nikolaos Mellios (CERTH),
Dimitris Kofinas (CERTH),
Konstantinos Kokkinos (CERTH),
Wojciech Froelich (US),
Ioannis Sarris (DEYASK),
Łukasz Podsiadło (RPWiK)

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Consisting of:

Organisation Name	Short Name	Country
UNIWERSYTET SLASKI	US	Poland
INSTYTUT EKOLOGII TERENOW UPRZEMYSLOWIONYCH	IETU	Poland
Rejonowe Przedsiębiorstwo Wodociągów i Kanalizacji w Sosnowcu Spółka Akcyjna	RPWiK	Poland
LOUGHBOROUGH UNIVERSITY	LU	United Kingdom
BRUNEL UNIVERSITY	BU	United Kingdom
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CENTRE FOR RESEARCH AND TECHNOLOGY HELLAS	CERTH	Greece
Dimotiki Epixirisi Ydreusis–Apoxeutesis Skiathou	DEYASK	Greece
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History

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3.0	Katarzyna Samborska	May 1, 2015	Final

Executive summary

This deliverable is a part of the Work Package 2 (WP2) that is pertained to data acquisition and structuring. This document describes the installation of the water consumption monitoring systems in demonstration sites in Greece and Poland.

The goals of the deliverable have been achieved. To the best of our knowledge, the installed wireless system is an innovative solution proposed by ISS-EWATUS. The deliverable also presents a unique solution in terms of localisations, where pilot installations take place. Poland and Greece are characterised by different type of water consumption monitoring and different water related problems.

The specific objectives of the deliverable related to the tasks and the state of their achievement is summarized in the following Table.

Objective	Task	Reached (Yes/No)	Outcome
Design a low cost wireless solution to remote, near real-time monitoring of water consumption	Task 2.2 Selection of sensors and their installation at households [page 7 of the DoW]	YES	The monitoring system consisting of sensors and data transmitters has been developed by the Loughborough University. **The outcomes are described in Section 1 of the report.**
Installation of monitoring systems in up to 20 households: 10 in Skiathos, Greece and 10 in Sosnowiec, Poland. (Addressing the comments of the reviewers of the project proposal, the number of 20 households has been increased to 40)	Task 2.2 Selection of sensors and their installation at households [page 7 of the DoW]	YES	In both demonstration sites: Sosnowiec in Poland and Skiathos in Greece, household monitoring systems have been installed. **In Sosnowiec** 10 households have been equipped with the monitoring system developed by the Loughborough University. According to the reviewers comments, aiming to extend the proposed system by an alternative set of sensors, additional 10 households have been equipped with the monitoring systems delivered by the commercial company APATOR POWOGAZ. **In Skiathos** 10 basic and 10 additional households have been equipped with the monitoring system developed by the Loughborough University. **The outcomes are described in sections 2.2 and 2.3 for the Polish site and in section 3.1 for the Greek site.**

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Due to the suggestions of the reviewers of the project proposal, the initial number of 20 households has been increased to 40. By means of the installation of additional 10 sets of commercial radio-read smart meters we will have the sole opportunity to compare both systems; commercial and non-commercial. Finally, by the installation of so many devices that continuously (every 30 seconds or couple of minutes) check the amount of water used for different purposes we have a plethora of very valuable data that can be used in future to analyse and change water habits.

The document is organized in the following way. Section 1 overviews the monitoring system, describes hardware and software components of the system. Sections 2 and 3 present the installations in Poland and Greece. Section 4 summarises the deliverable.

The report is supplemented by 3 appendices. The first one presents detailed instruction on how to configure the data transmission system for the household monitoring system. The second appendix contains the review of existing water monitoring systems. The third presents details on commercial flow meters and data transmitters that have been installed in additional 10 households in Poland.

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Introduction

The global water crisis is a number one amid risks impacting the society (as a measure of devastation), and on the eighth place of global risks with the highest likelihood of occurring within 10 years, this message was announced by the World Economic Forum in January 2015. Nowadays, almost 750 millions of people do not have access to clean water and we have to be aware that this number will grow. Some parts of western, modern world becomes not much different from areas of third world affected by water shortages. A deadly heats, extreme precipitation, droughts convince many in Europe that climate changes are shaping our present day and we have to cope with them. The gradual increase of temperature will cause that in many areas water will be less available, even now the water scarcity affects 17% of EU territory. In the light of these disturbing facts any cause of wasting water should be identified and removed. The main stress to the water resources is also due to growing population and its higher water demand. In order to save water in the framework of sustainability, Information and Communications Technologies (ICTs) combined with smart water meters, can provide customers the indispensable information needed so as to adopt sustainable behaviors and lifestyles over water consumption. Recent research work by Anda et al., (2013) focused on a smart metering trial, which was incorporated into a residential water efficiency project in Perth, Western Australia. The project engaged 12 000 households in selected suburbs of the Perth metropolitan area, where smart meters were installed, providing an informative and educational tool, allowing customers to instantaneously view personal real time water use feedback. Data selected concerned water use before customers had feedback for their consumption and afterwards. By comparing the two data series Anda et al. had the opportunity to compare users' differential behavior and conclude that real-time access to water consumption data encouraged significant water saving. The study showed that users getting feedback, decreased the water consumption up to 60%.

Building public support to water management policies requires raising stakeholder awareness of resource problems and understanding about the effects of different policy options.

Stave (2003) conducted a system dynamics modeling approach to facilitate public understanding of water management options in Las Vegas, Nevada. The study revealed that, concerning that case, reducing residential outdoor water use (restaurants, hotels, etc.) has a much greater effect on water demand than reducing indoor water use.

Various research works have shown that householders' perception of their water consumption differs from their actual water use. A 2013 study (Beal et al., 2013) presents a novel mixed method smart metering approach to reconciling differences between perceived and actual residential end use water consumption. Beal et al point out that there is little research on the socio-demographic and socio-psychological drivers of this phenomenon. That particular study included high resolution smart metering of end use water consumption, psycho-social and socio-demographic surveys, stock inventory audits and self-reported water diaries for 252 households located in South-east Queensland, Australia. Variables such as income, family size and composition and percentage of water efficient stock (e.g. low-flow taps) were examined. The authors conclude that increasing consumers' information on their household water consumption will raise their awareness and understanding of water use and encourage more conservative water use behaviors.

Boyle et al. (2013) provided a review concerning the revolutionary engagement impact that smart water metering arises. The review analyzes drivers, development and global deployment of intelligent water metering in the urban context. Boyle et al. highlight the critical importance of end-use detail that smart metering provides to improving water demand forecasting models and identifying challenges to be tackled. They point out the issue of data privacy as one demanding the attention of utilities and regulators. Finally, they conclude that smart metering is going to play a significant role in the near future utilities water management policies.

A recent smart metering and billing survey conducted by Liu et al. (2014) investigated the efficiencies of different water user engagement methods. The survey examined three key components of informational content, the units in which smart metering feedback is given (water volume, price), comparators among the same household or between different

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households and advice. The results obtained showed that consumption data in dollar terms makes data more meaningful, while the consumers seem to be more interested in information at end-uses level in the household and in comparing their own consumption with other household end-uses. Most preferable data feedback was proven to be the weekly-basis, rather than daily or monthly.

The 2010 Final Report of the Smart Water Metering Cost Benefit Study relates customer impacts to customer empowerment, household leaks, changes in billing, smart water appliances and customer relationship management. In this report, contrary to the Liu et al. (2014) study it is suggested that Water Authorities would gain improved benefits by providing their customers feedback concerning water consumption on a daily basis rather than weekly.

Okaka and April (2013) examined Innovative ICT Public Awareness Campaign Strategy to Communicate Environmental Sustainability in Africa. In this study gender, education level and socio-economic related aspects are highlighted as of great importance in the effect of ICTs use to behavioral changes. Low income and education are barriers to informational access and therefore to the possible ICTs beneficial influence. Great focus must be given on selecting proper ICTs and media forms according to the socio-economic peculiarities. Concluding, "ICT is the most efficient means of disaster risks and other forms of risks communications strategies. It defies geographic boundaries, locations, and it is effective in real time circumstances. Its versatility, affordability, ubiquity, and accessibility, makes it a frontline technology for all environmental, social, economic, and policy or legal related telecommunication asset of this century".

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1 A novel wireless water consumption monitoring system at household level

The wireless monitoring system has been developed by Loughborough for the ISS-EWATUS project, where the flow sensor is an off-the-shelf product and the wireless data collector and wireless gateway are tailored according to the requirements of ISS-EWATUS.

1.1 System overview

The novel, wireless household water consumption monitoring system consists of one Wi-Fi router, one 433-WiFi gateway, and several wireless data collectors (Figure 1). The system gateway can be configured wirelessly through smartphone, PAD, PC and other mobile devices at the household where the system is located. Alternatively a local PC can be also used for configuration through a standard Ethernet. The remote central data server is responsible for receiving the data sent by the wireless monitoring system through any Internet connection. A remote server software to receive the sensed data across Sosnowiec in Poland and Skiathos in Greece has been also developed as a part of the system.

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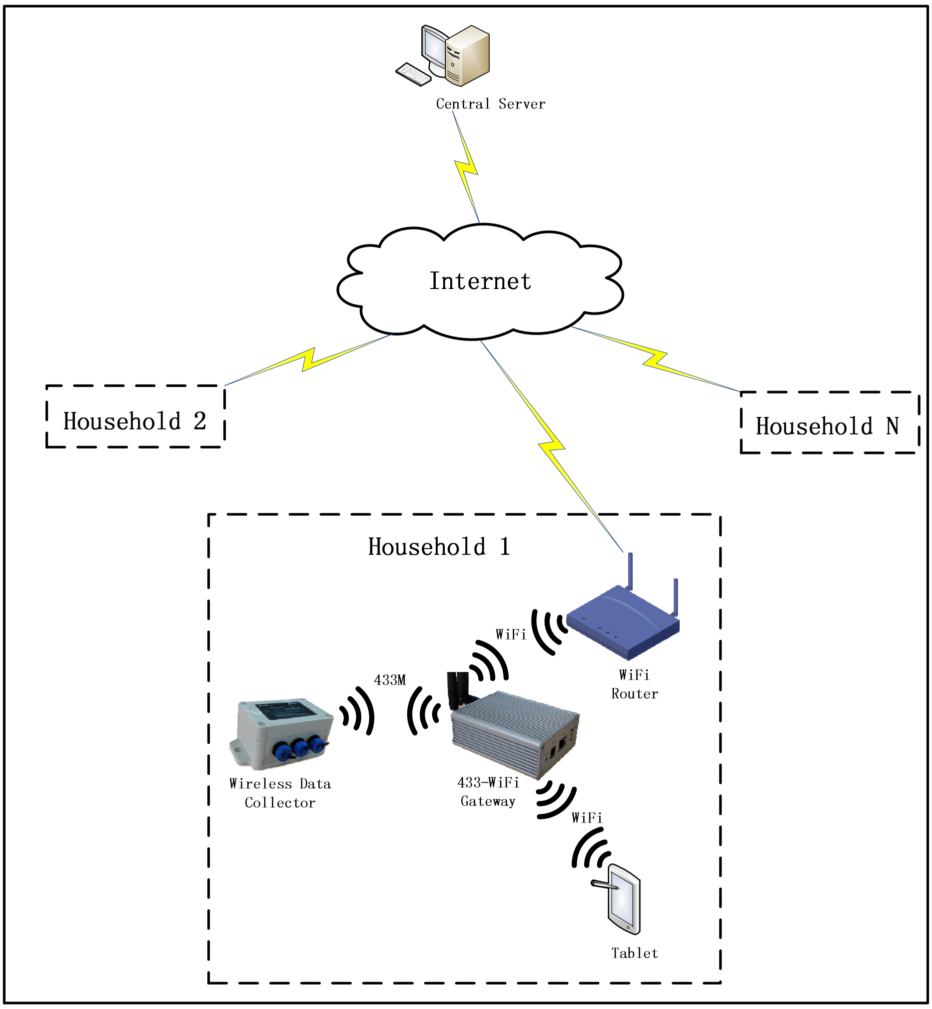

Figure 1. Wireless household water consumption monitoring system architecture

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1.2 Hardware development and installation

The monitoring system has been tested in three steps, firstly testing in the Laboratory in Loughborough University after finishing the design, development and hardware manufacturing. The test rig in Loughborough University is shown in Figure 2. Secondly, a single system has been installed in a domestic house in Sosnowiec in Poland and in Skiathos in Greece respectively. The server in Poland was configured to collect data from monitoring systems in both countries.

Figure 2. Test rig for water consumption monitoring at Loughborough University

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Gateway device

A tailed wireless gateway has been developed as shown in Figure 3 with the indicators shown in Table 1 and back panel in Figure 4.

Figure 3. 433-to-WiFi gateway device

Figure 4. 433-to-WiFi gateway back panel

Table 1. Gateway Indicators

433-to-WiFi gateway	Identi-fiers	Description
Front Panel	LAN	local configuration interface, connect with 10/100BaseT-Ethernet network card
	DC IN	5V DC power input port
	RESET	long press for 5s to wipe user data and restore factory defaults
Back Panel	433M	433M antenna interface
	WIFI	2.4G WIFI antenna interface
Indicator Light	Power	Indicator lights up when normal supply of power is on
	433M	Always in off state and one flash when receiving data from wireless data collectors
	WIFI	Indicator lights up when module connects with router and sending data out

The 433-to-WiFi wireless gateway has two functions, receiving data from one or more 433-wireless data collection nodes through a 433 communication channel and converting the signal into Wi-Fi signal and passing to the household Wi-Fi router. It works regularly in a pre-defined interval even though data received from 433-wireless data collection nodes may arrive at the gateway at any moment. There is no synchronization mechanism between data collection nodes and the gateway. The information flow of wireless gateway is presented in figure below (Figure 5)

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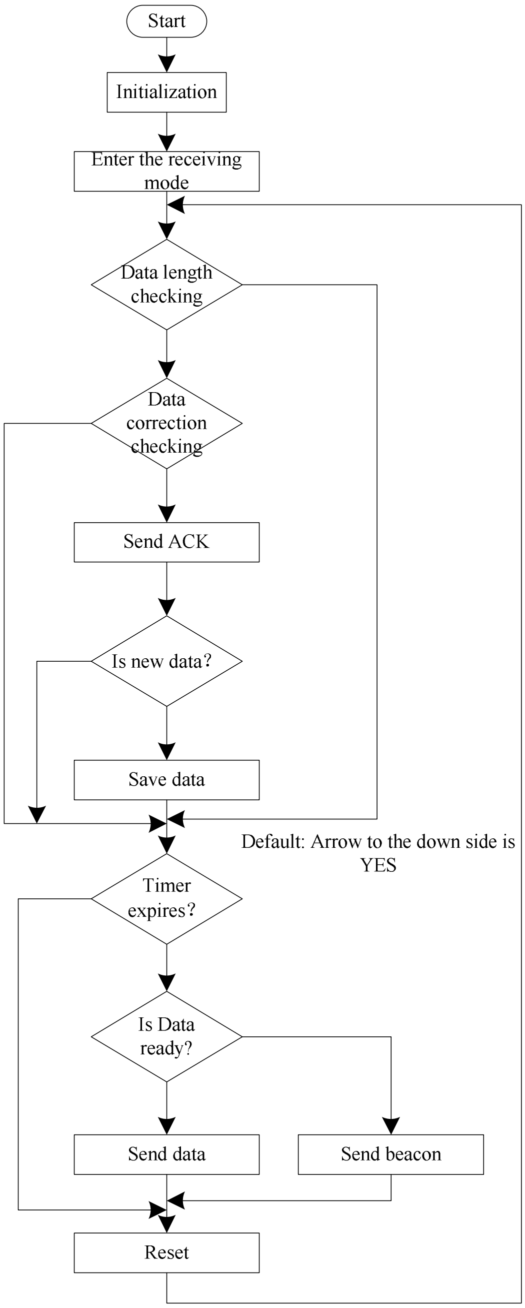

Figure 5. Information flow of wireless gateway

The gateway is mains powered and can join a Wi-Fi home network and also can be connected by other smart mobile devices for facilitating future Decision Support Systems. The technical specification of the gateway can be found in the Table 2.

Table 2. Gateway technical specification

Working voltage	DC 5V
Working current	≤200mA
Size	33*103*120mm
Material	6063T Extrusions
Surface treatment	Sandblasting
WiFi Protocol	802.11 b/g/n
WiFi Frequency	2.412GHz-2.484GHz
WiFi transmit power	≤20dB
Network communication protocol	TCP/UDP/ARP/ICMP/DHCP/HTTP
Ethernet speed	100Mbps
Security	WEP/WPA-PSK/WPA2-PSK/WAPI
MaximumTCP connection	32
Working temperature	-25-85⍰
Working humidity	10%~85%RH
Storage temperature	-40-100⍰
Storage humidity	5%~95%RH

Wireless data collector

The tailed wireless data collector was designed to collect water flow rate and water temperature and then wirelessly send to the 433-WiFi gateway. No configuration is required as the data collector will automatically connect with the nearest 433-WiFi gateway and the detailed information flow of embedded software in the wireless data collector is presented below (Figure 6).

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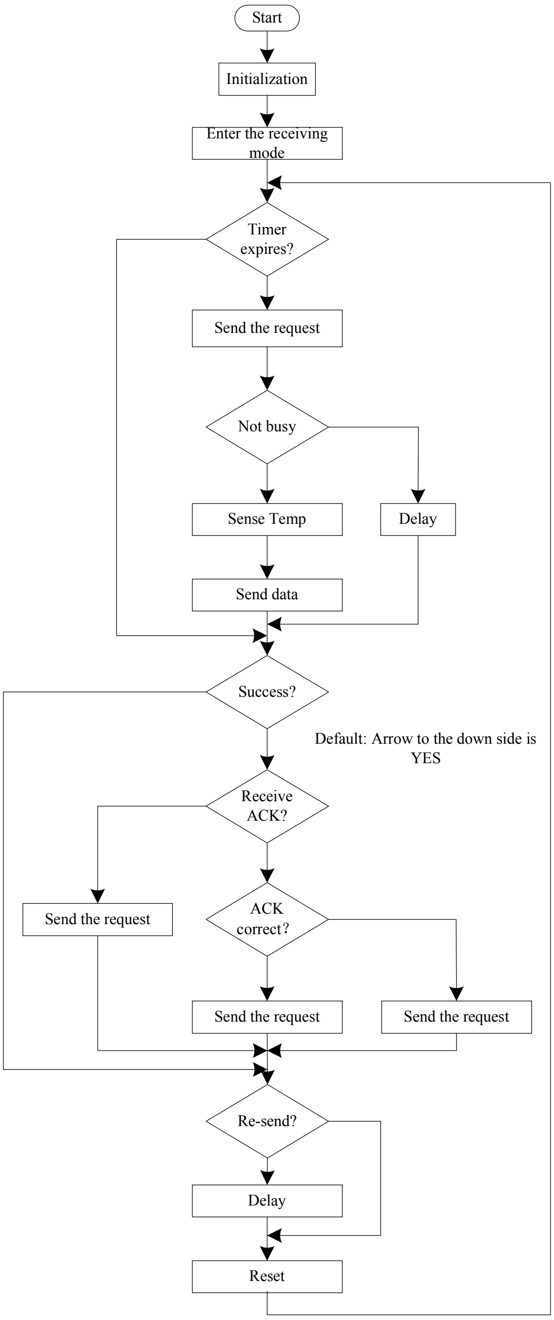

Figure 6. Information flow of wireless data collector

Two types of the wireless data collectors have been manufactured as shown in Figure 7, one with dual sensors which can be connected with two flow rate/temperature sensors and one with a single sensor which can only be connected with one flow rate/temperature sensor. The data collector uses a 5V DC power. The power connection is different from the sensor socket. There is no way to make an incorrect connection.

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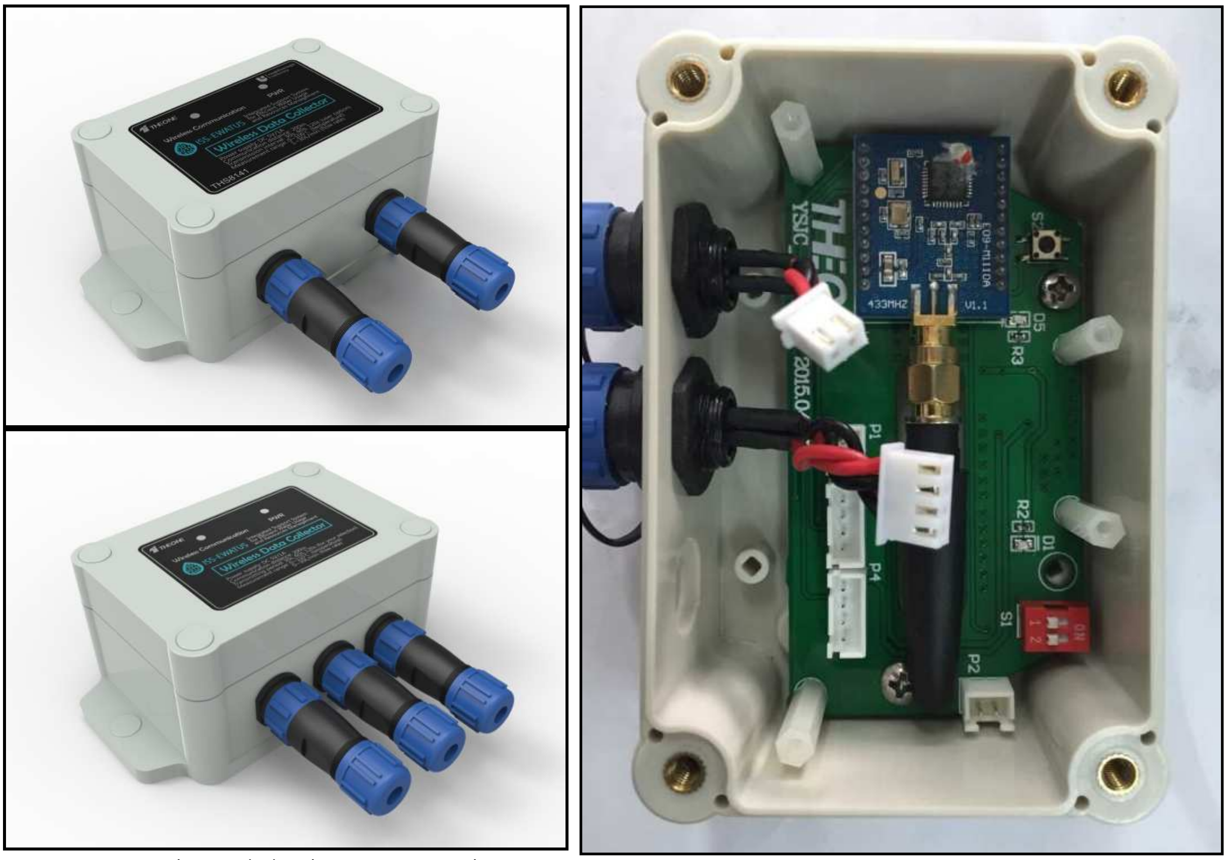

Figure 7. Single and dual sensor wireless data collector

The panel layout and the indicators of the wireless data collector are shown in Figure 8 and Table 3

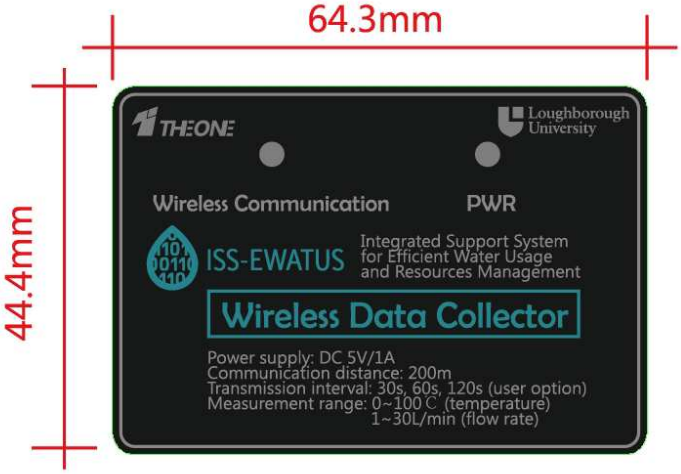

Figure 8. Panel layout of the wireless data collector

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Table 3. Indicator of wireless data collector

Wireless Data Collector	Identifiers	Description
Front Panel	DC IN	5v DC power input port
	Sensor 1	Water flow rate/temperature sensor
	Sensor 2	Water flow rate/temperature sensor (only for dual sensor wireless data collector)
Indicator Light	Power (PWR)	Indicator lights up when normal supply of power is on
	wireless communication	Always be off and be flash when sending data out

The wireless data collector has the following features:

- Power: standard 5V DC from mains power adaptor.
- Network topology: Many to one star network. Support maximum 10-nodes to 1-node star communication.
- Signal transmission: one way signal transmission, a delay collision avoidance is used.
- LED Indicators: Power LED and Communication LED. When data is transmitting the LED will be flashing. The power LED indicates the power supply status (on or off).
- Power switch: No power switch. Start when power is on.
- Power saver mode: The data collection node constantly detects the status of the flow rate sensor. In the status of zero-flow the transmission node will be in a sleep mode and stopping data transmission for energy saving. Once any none zero-flow is detected the transmission node is activated and the transmission is resumed.
- Configuration: The sensor reading rate is fixed at one second in order to catch the real-time feature of the water consumption, but the transmission rate, called sampling interval, can be pre-specified as “Fast”, “Middle”, or “Slow” by setting a dial switch inside the closure of the data collector.

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The detailed technical specification of the data collector is presented in Table 4.

Table 4. Data collector technical specification

Working voltage	DC 5V
Working current	≤30mA
Size	128*70*52mm
Material	ABS plastic
Frequency	433M
Transmit power	10dB
Data rate	1.2kbps
Maximum transmission distance	200m
Indoor transmission dis-tance	≤50m
Working temperature	-20~+80□
Working humidity	10%~85%RH
Storage temperature	-40~+100□
Storage humidity	5%~95%RH

Flow rate and water temperature sensor

The flow rate/temperature sensor which was used in connection with the data collector is presented in Figure 9 and its technical specification can be found in the table below (Table 5).

Figure 9. Water flow rate/temperature sensor

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Table 5. Water flow rate and temperature sensor technical specification

Working voltage	DC 5V
Maximum current	15mA (DC 5V)
Interface	G1/2
Load capacity	≤10 mA (DC 5V)
Working temperature range	≤80⍰
Working humidity	35%~90%RH (Frost-free status)
Water pressure	≤1.75Mpa
Storage temperature	-25~+80⍰
Storage humidity	25%~95%RH
Flow accuracy	F=7.5*Q, error≤2%
Measurement range	1-30L/min
Output duty ratio	50%±10%

1.3 Server software

The server software has been developed using Visual Studio 2012 and Microsoft SQL server 2014. The server requires .NET framework 4.5 or above. As shown in Figure 10 the server application is divided into four levels. The lowest level is database, this level is responsible for connecting to the database and supplying a connection interface to the upper level. The database operator level operates the database by utilizing the database operator interface. The most important level in this application is the data process service, the data encapsulated enter the application through this level and transfer to other levels. The listening socket receives data from the server port and transfer these message to the data process service. Response socket aims to send the request of corresponding data back to the sensor devices if necessary. The upper level is the windows form, which contains all of the visual component and event processes. The window form is operated by the administrator with access control.

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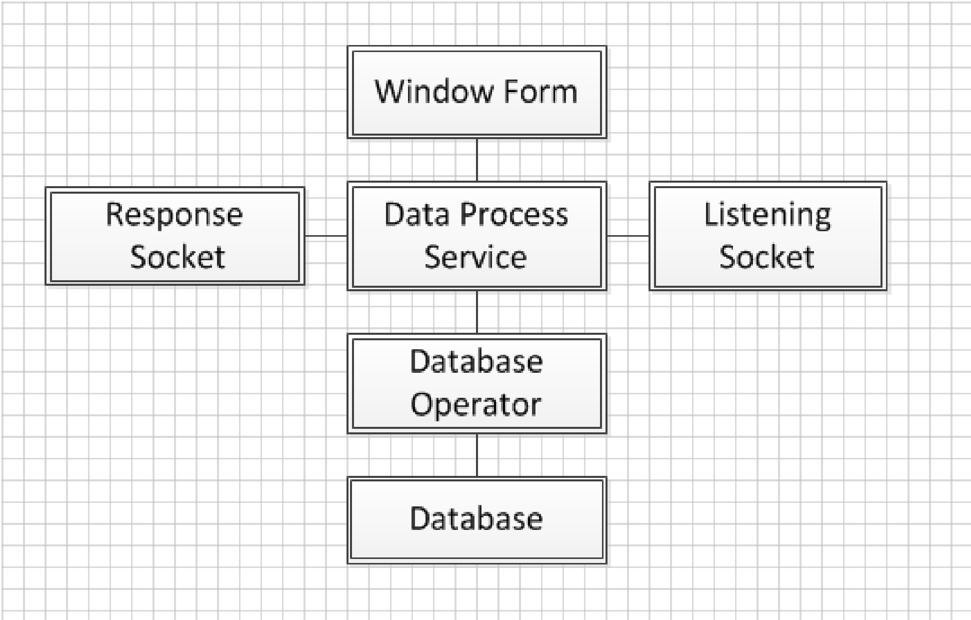

Figure 10. The architecture of the server software.

The configuration of the system is described in details in Appendix 1.

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2 Case study in Poland

Study area is situated in Sosnowiec, southern Poland. The city is located in the Upper Silesian Industrial Region and is a part of the Upper Silesian Metropolitan Area populated by about 5 294 000 people. The population of the city is 220 000 (2012).Sosnowiec is located about 10 km east of Katowice that is the capital of the Silesian Voivodship.

2.1 Water consumption monitoring in Sosnowiec

The Water Supply and Sanitation Company in Sosnowiec has a very impressive and modern monitoring system of the municipal water consumption. In 2014 there was c.a. 14 000 radio-read water meters. These appliances are equipped with the communication Cyble modules of the Itron company that enable remote reading. The Cyble system represents a new concept of the two-direction data transmission, which eliminates the disadvantages of the pulse generators. The basic elements of the system are communication modules installed directly on the water meter. There are several types of such modules: Cyble sensor, Cyble M-Bus and Cyble Anyquest Basic and Enhanced, Cyble RF and Cyble Everblue.
The system used by the Regional Water Supply and Sanitation Company consists of Cyble Sensors and Cyble RF Sensors. The latter transmits data on water consumption in a form of pulses. This device can be used in places with difficult access wherein the traditional radio module cannot work properly due to insufficient range of signal or muffled signal. In turn, the water meters equipped with the RF module are read by means of the drive-by method. It means that readings are carried out by an employee, in a vehicle, equipped with the PSION Work About terminal. Data reading can be conducted from a distance of dozens meters. The module mounted on the water meter "responses" only if there is a direct request from the PSION terminal (Figure 11). The bidirectional transmission extends the battery life, allows for remote programming and does not "pollute" the electromagnetic environment by a continuous emission of radio waves. The software provided by the Itron company allows for pre-

paring the reading routes, analyzing of data and transferring them to the billing system (Kom-Media).

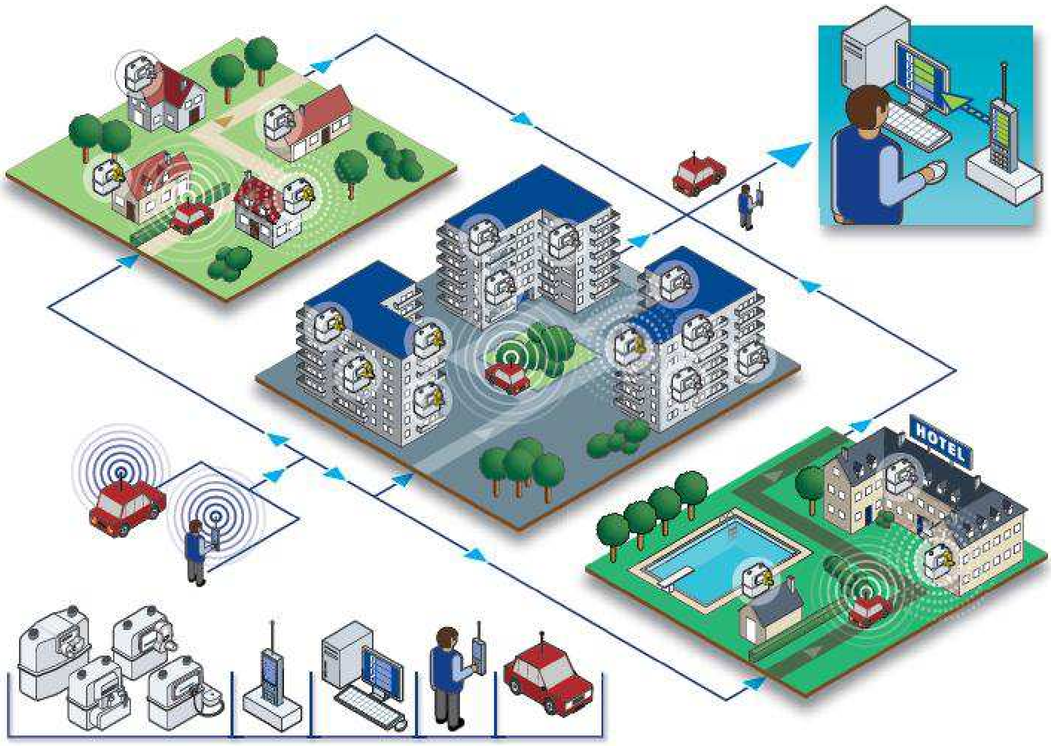

Figure 11. The drive-by system using the Psion terminal and radio-reading modules (source: Itron)

2.2 Implementation of the basic water monitoring system

Trial installation at the selected household

On the 28th November 2014 the wireless water consumption monitoring system has been tested in one selected household in Sosnowiec. It has to be mentioned that searching for volunteers in Sosnowiec has not been an easy task. Among main obstacles were scepticism (people were not convinced that detailed monitoring of the water consumption is important), unjustified fear that some habits may be exposed and lack of motivation (people were looking for some special benefits). Eventually, 10 household were selected, in the first of them the part of the monitoring system has been successfully implemented with the as-

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sistance of professional plumbers. The implementation was carried out in the kitchen where the access to electric sockets was feasible. In Figures 12, 13 and 14 parts of the installed system are presented, whilst in Figure 15, the real-time data transmission from sensors is presented.

Figure 12. Flow sensor is mounted on the hydraulic adapter

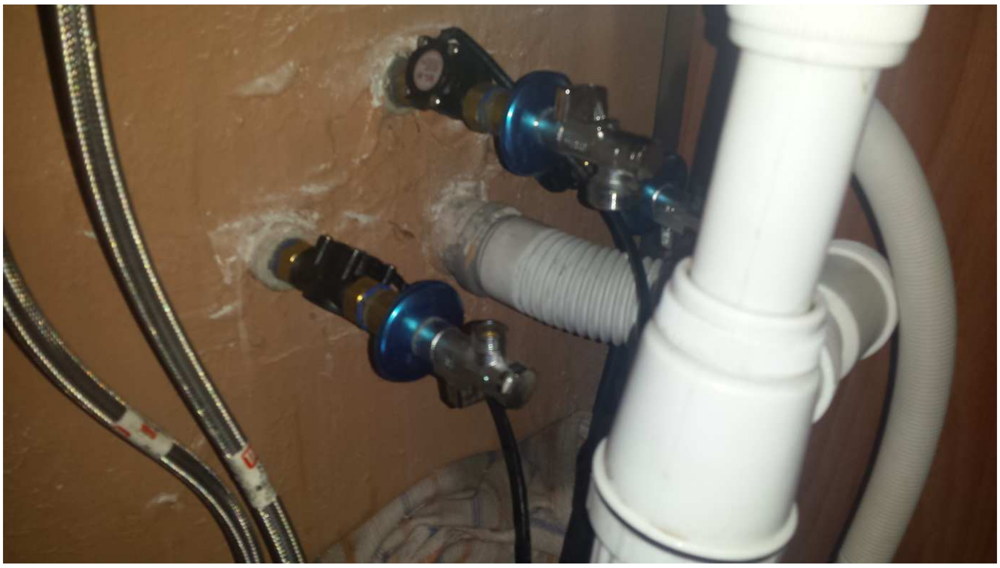

Figure 13. Several flow sensors are joined with the water supply pipes

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Figure 14. Flow sensors are connected to data collector nodes (one collects data from the tap and second from the dishwasher), nodes are mains powered

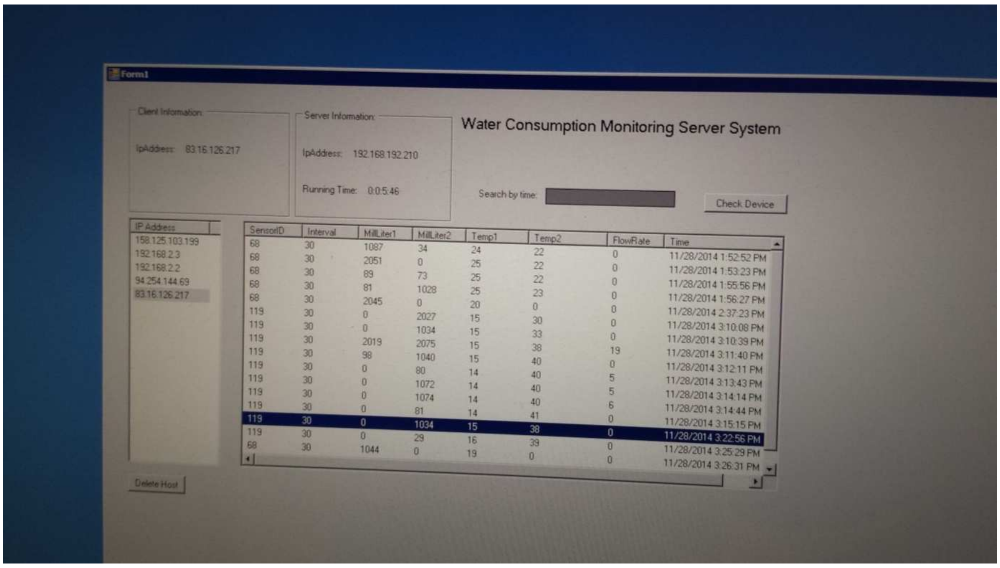

Figure 15. Data transmission window, data for temperature, flow for two sensors (ID 68 and 199)

Implementation of the water consumption monitoring system at households

Prior to the implementation, on the 22nd of January 2015 each household was visited by IETU with the assistance of professional plumber. During the visits the possibility of installation of monitoring sensors and transmission nodes was assessed for each water outlet in each

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household. As the effect the list of sensors and data collectors/nodes along with the required power strips was prepared:

- Sensors: 46
- Transmitters: 31
- Power strips:

		Cord length			
		1	2	3	4
Sockets	2	2			
	3	3	2	4	1
	4	1			

- Multi socket adapters:

Sockets	Pieces
2	6
2 / 3 flat	1

Basing on the visits, a hydraulic services company prepared a list of required installation parts such as pipes, hoses, pipe fittings and couplings. Moreover, some hydraulic connectors needed for the installation of sensors were prepared in advance for each installation place. Usually these connectors consisted of two pipe fittings of appropriate diameters connected by a flexible hose. Such preparatory work significantly sped up the sensors mounting.

The whole set of monitoring systems has been manufactured in February 2015. The full scale installation in Sosnowiec was carried on the 6th and 7th of March 2015. The monitoring system provider - Loughborough University and the professional plumber conducted the installation work. Installations included setting up monitoring systems in 9 households and replacing the gateway to the new version in the pilot households. In total 10 monitoring systems have been installed and tested in two days. After each installation a data transfer from the monitoring system to the dedicated server at IETU has been successfully tested (Figure 16). Installation of one monitoring system required approximately 1,5 hour including the local transportation and the preparatory visits required additional hour for each household.

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Sosnowiec Water Consumption Gateway Status Summary

RouterId	IpAddress	Status	LastUpdate	SensorNum	MeasurementNum
1	88.220.124.198	1	4/6/2015 1:22:15 PM	1	2
2	89.77.210.218	1	4/6/2015 1:21:51 PM	2	3
3	88.220.124.198	1	4/6/2015 1:22:07 PM	1	2
4	89.77.208.39	0	3/31/2015 8:14:51 PM	1	2
5	89.74.147.173	1	4/6/2015 1:21:47 PM	1	1
6	83.16.126.217	0	4/2/2015 8:23:30 PM	1	2
8	89.68.208.46	1	4/6/2015 1:22:16 PM	1	2
9	89.79.252.153	1	4/6/2015 1:21:54 PM	1	2
c	79.175.209.82	0	3/28/2015 3:48:54 PM	1	2
e	89.79.12.130	1	4/6/2015 1:22:14 PM	1	2

Figure 16. Web service presenting the status of monitoring systems in Sosnowiec

2.3 Implementation of the additional water consumption monitoring system

In case of the ISS-EWATUS project, reviewers of the proposal suggested adding more demonstration sites for the water consumption monitoring system at the household level. The initial number of 20 households (10 Greek and 10 Polish) is not quite representative (statistically it is a small sample < 30).Thus, the additional monitoring system had to be selected/designed and installed in selected houses. At the beginning of discussions, the simple smart meters dedicated to monitor only single outlets were excluded as a not very accurate and incomplete solution. Moreover, most of the simple "smart" meters dedicated for individual use, not for billing purposes, are at the stage of startups and project Partners could not risk to invest money and time in unverified solutions since all installations were planned in the first year of the project. Eventually, only commercial solutions were considered. After sending a request for proposals to suppliers, basing on the price offered, long-term experience of suppliers, way and frequency of data collection, technical support and other factors the Apator Powogaz company has been selected. The brief description of the system can be found in section 2.3 and Appendix 3. The installation of monitoring system was performed in one building (one staircase). In each of 10 selected households 7 water meters equipped with the radio-modules were deployed (Figures 17- 18).

Figure 17. Top: Six water meters monitoring hot and cold water (kitchen tap, bathtub tap and bathroom tap); bottom: Water meter mounted on the toilet flush

It is worth mentioning that the installation made by the Apator company is a comprehensive one. It means that the water use for all household purposes will be continuously measured. Of course this task required rearranging of the whole water installation and wall demolition (Figure 18). Besides water meters, required retransmitters and one data collector was placed

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in the building. The collected data are stored in the designed database on the dedicated server.

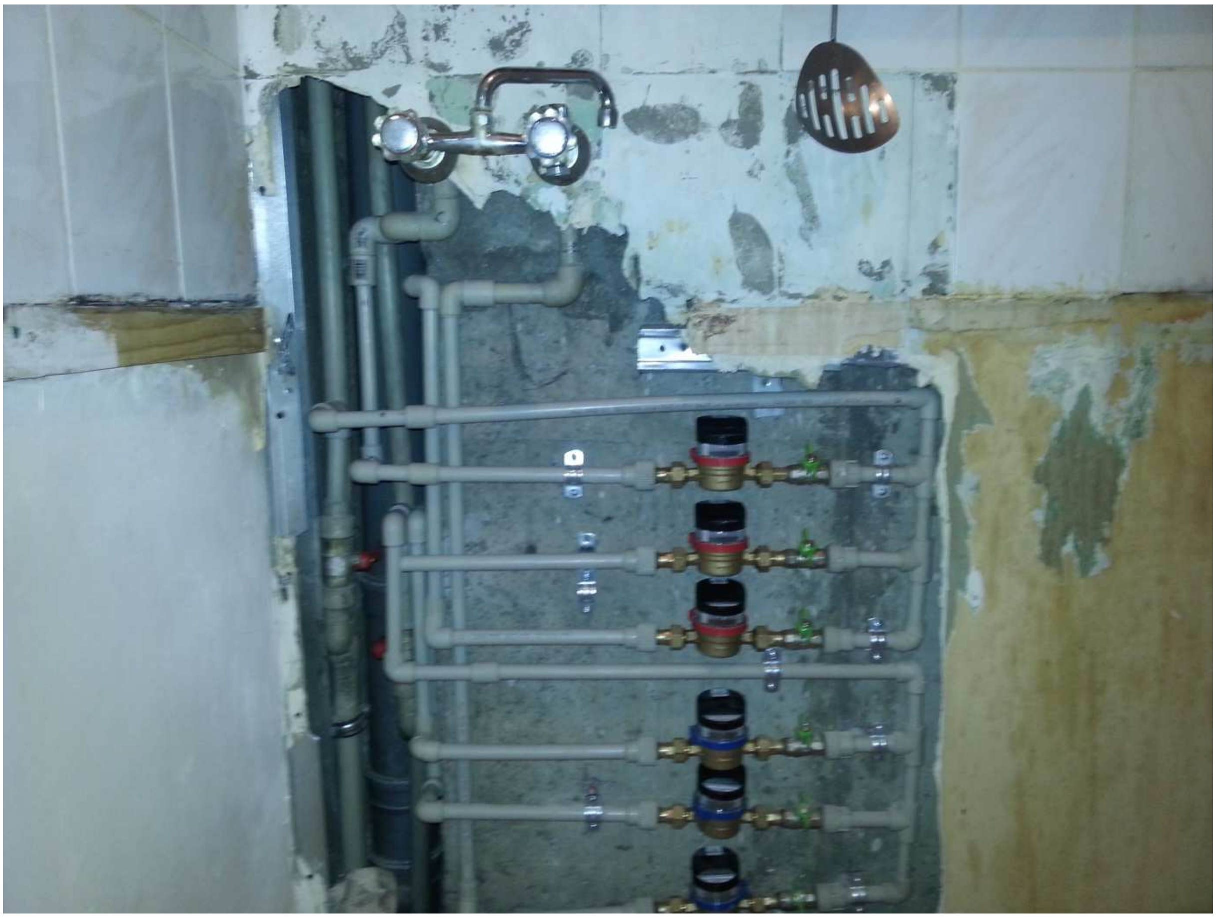

Figure 18. Water meters after the installation

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3 Case study in Greece

The island of Skiathos, which belongs to the complex of North Sporades, occupies an area of 50 km^2 and has 44 km of coastline. The higher parts of the island are located in the north-northeastern part, while the lowest in the east and southeast tip of the island. It has about 5 000 inhabitants living mainly from the tourism and agriculture. Many inhabitants leave the island in the winter and work in mainland Greece. The south side of the island has a large touristic development, while the north remains pristine and unexplored. More details about the study area can be found in the deliverable 2.1 "The installation of sensors at urban level".

3.1 Implementation of the basic and additional water use monitoring system

Trial installation at the selected household

On the 30th and 31st of January 2015 the wireless water consumption monitoring system has been installed in a selected household in Skiathos in Greece. Figures 19 and 20 show the layout of the installation. A number of new features have been added in the software such as live signal of the gateway for monitoring the status of the system remotely from the central server compared with the system installed in Sosnowiec.

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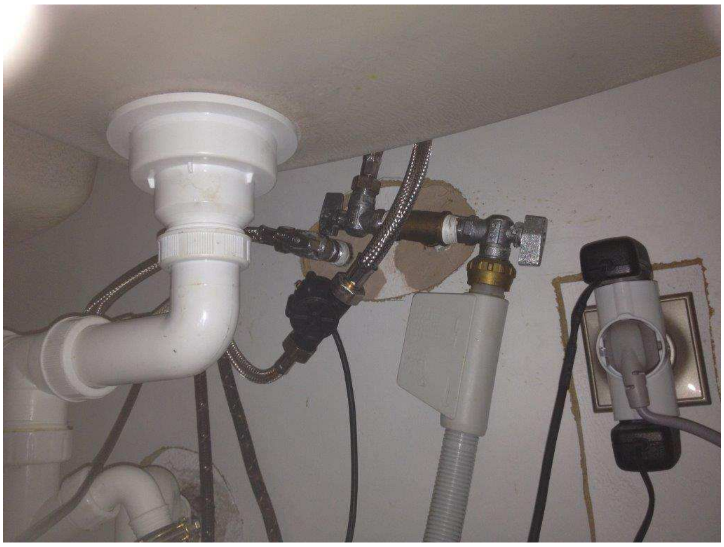

Figure 19. One flow/temperature sensor is installed with the water supply pipes

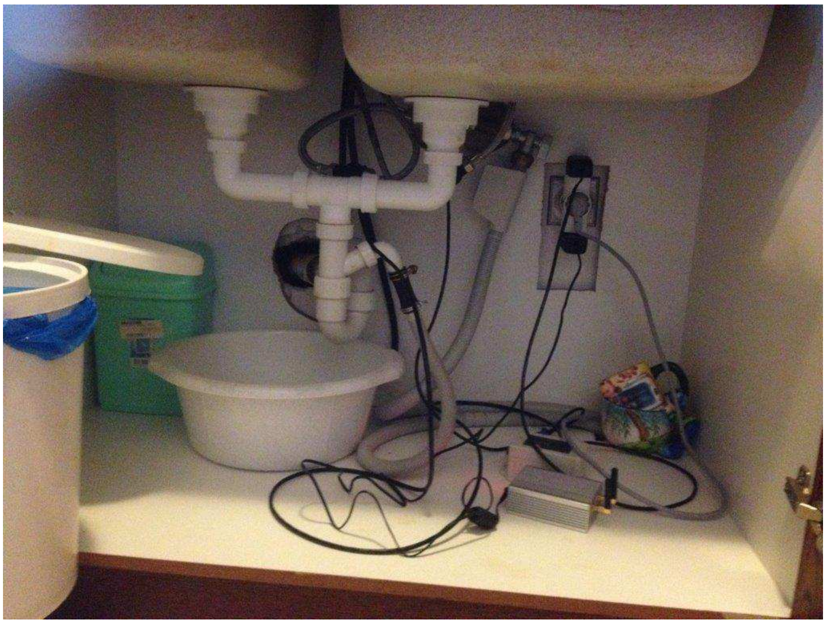

Figure 20. Flow/temperature sensor and the gateway are installed in a household

Full implementation of the water consumption monitoring system at households in Skiathos

After the successful installation of the monitoring system in the pilot household in Skiathos, a whole set of water consumption monitoring equipment was also installed in 19 additional households, similarly to the Sosnowiec case. The selection of the households in Skiathos Is-

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land was made with the criteria of willingness of household owners to participate and the representativeness of the sampling and the availability of Wi-Fi connection of each house.

Participants agreed to install a set of hot and cold sensors under the kitchen tap. However, the installation of sensors for the dishwasher sensors was avoided due to the following reasons:

- Either the water supply to the dishwasher was with the same pipeline that supplies the kitchen sink with cold water or
- The installation of the dishwashers (this is the most popular installation) is in a compact mode where the connection to the power supply and the water pipe is exactly behind the dishwasher and the equipment is packed in an autonomous cabinet without allowing access to the water-line without major renovation, making participants to be reluctant to follow this choice.

Installations were divided into two parts. The first one completed on the 4th and 5th of April, 2015 included 9 households, so in total 10 households were equipped with monitoring systems. All new sets of monitoring devices started data transmission to the server located in IETU immediately after the installation.

The second part of installations took place on the 18th and 19th of April 2015, and this time 10 additional households were equipped with monitoring system with the assistance of representatives of the Loughborough University.

In figure 21 the installation process at different households in Skiathos is presented.

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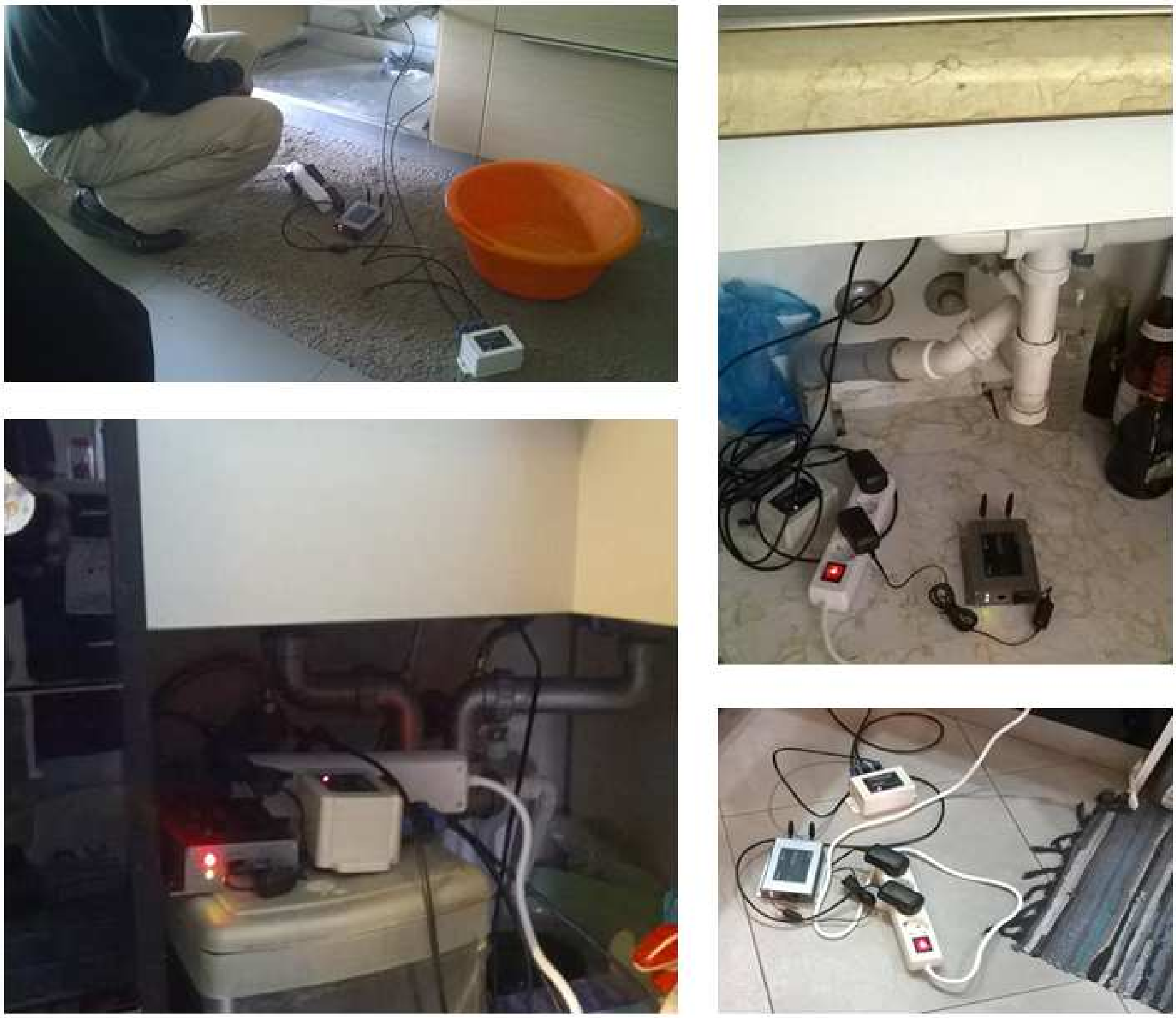

Figure 21. Installation of household consumption monitoring system

All devices were successfully installed and appropriately configured to join the household Wi-Fi network in order to transmit accurate water consumption data to the dedicated server of this project. The following screenshot shows the status of the devices of Skiathos on the server.

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Skiathos Water Consumption Gateway Status Summary

RouterId	IpAddress	Status	LastUpdate	SensorNum	MeasurementNum
10	79.131.137.56	1	4/29/2015 9:47:14 PM	1	2
11	85.73.107.145	0	4/29/2015 9:36:18 PM	1	2
12	94.68.41.169	1	4/29/2015 9:47:28 PM	1	2
13	2.85.89.142	0	4/23/2015 7:21:19 PM	1	2
14	2.85.95.111	0	4/29/2015 5:02:00 PM	1	2
15	94.66.134.29	1	4/29/2015 9:47:15 PM	1	2
16	85.73.103.230	1	4/29/2015 9:47:15 PM	1	2
17	79.131.133.78	0	4/29/2015 7:22:45 AM	1	2
18	94.69.221.252	0	4/29/2015 3:48:50 PM	1	2
19	94.66.181.143	0	4/29/2015 6:58:36 AM	1	2
1a	2.85.95.103	1	4/29/2015 9:47:18 PM	1	2
1b	94.66.151.218	1	4/29/2015 9:47:29 PM	1	2
1c	94.64.20.230	1	4/29/2015 9:47:18 PM	1	2
1d	79.131.130.191	0	4/27/2015 12:53:28 PM	1	2
1e	94.66.178.125	1	4/29/2015 9:47:26 PM	1	2
7	79.167.175.193	1	4/29/2015 9:47:10 PM	1	2
a	87.202.124.83	1	4/29/2015 9:47:13 PM	1	2
b	94.66.167.102	1	4/29/2015 9:47:27 PM	1	2
d	94.66.182.58	1	4/29/2015 9:47:08 PM	1	2

Figure 22. Screenshot of the web application that monitors the Skiathos Water Consumption Gateway Status.

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4 Summary

The installed water consumption monitoring systems will put more light on our daily habits and will help to change it. In case of Poland two complementary monitoring systems have been tested:

- The First includes 10 households and is dedicated to this project as a novel, non-commercial system.
- The Second, includes commercial solution based on the Mbus technology. It has been also installed in 10 households.

In Greece (Skiathos):

- 10 planned households have been equipped with the water consumption monitoring system provided by the Loughborough University.
- Following the request of project proposal reviewers, additional 10 water consumption monitoring systems have been installed in additional 10 households. T

The water monitoring system has been successfully integrated with the ISS-EWATUS databases and the data collecting process has been initiated just after each installation. In total 40 water consumption monitoring systems have been installed and coupled with dedicated databases to transmit the data in near real-time.

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Beal, C. D., R. A. Stewart and K. Fielding, 2013, A novel mixed method smart metering approach to reconciling differences between perceived and actual residential end usewater consumption, Journal of Cleaner Production, 60: 116-128.

Boyle T., D. Giurco, P. Mukheibir, A. Liu, C. Moy, S. White and R. Stewart, 2013, Intelligent metering for urban water: a review, Water, 5: 1052-1081.

Liu A., D. Giourco, P. Mukheibir and G. Watkins, 2014, Smart metering and billing, information to guide household water consumption, International Conference on Peri-Urban Landscapes: Water, Food and Environmental Security, Proceedings 73-77.

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Stave K. A., 2003, A system dynamics model to facilitate public understanding of water management options in Las Vegas, Nevada, Journal of Environmental Management, 67: 303-313.

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Appendix 1. Configuration of the water consumption monitoring system

Connecting mobile device with 433-to-wifi gateway

- Step 1. Go to control Panel and then select Network and Sharing Centre. Make sure that the adapter settings to configure Internet protocol of local connection or wireless network connection is at 'Obtain an IP address automatically' and 'Obtain DNS server address automatically'.

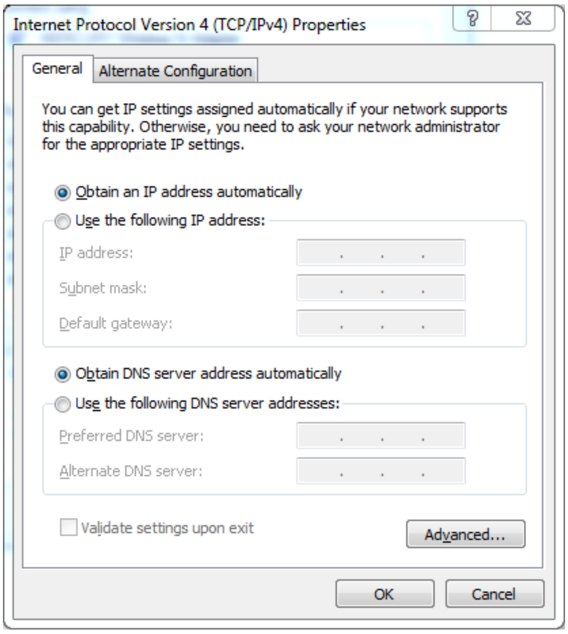

Figure 23. Mobile device network setting

- Step 2. Select the 433-to-WiFi gateway ((default SSIS: USER-WIFI232-AP_XXXXX where XXXX will be different from gateway to gateway) and connect your device with the gateway. If joining the network successfully, you will see a pop-up window and then move to the next step.

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Figure 24. Connecting the 433-to-WiFi gateway

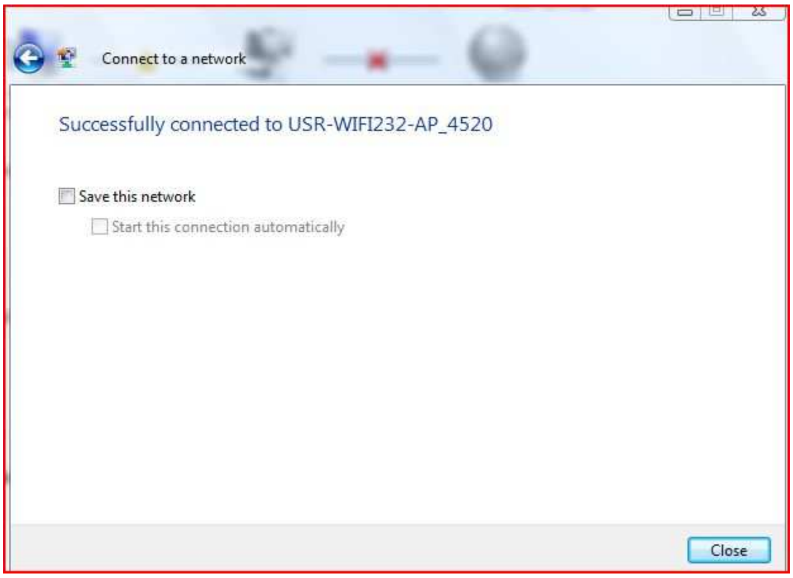

Figure 25. Successfully connected to the 433

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Accessing the 433-to-wifi configuration page

- Open any Internet Browser and type in 10.10.100.254 in the browser and a pop-up window will be displayed and ask for username and password (Figure 26). Input 'admin' as the username and 'admin' as the password to enter the 433-to-WiFi configuration page shown in Figure 27.

Figure 26. Login page of the 433-to-WiFi configuration page

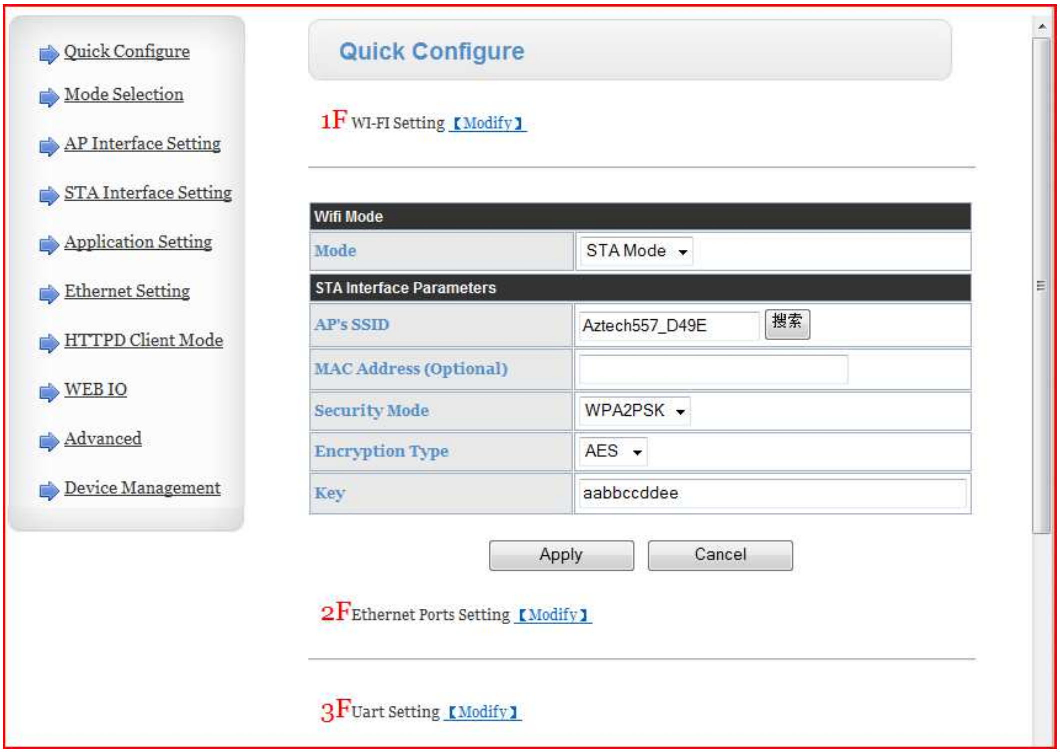

Figure 27. 433-to-Wi-Fi configuration page

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Configuring 433-to-wifi gateway

The configuration of the gateway is stepwise, as follows:

- Step 1. Choose 'Mode Selection' to enter 'Working Mode Configuration' page and then choose 'STA Mode' (station), click 'Apply' button (See Figure 28) and a successful setting window will pop out and shows 'Set Successfully, Restart to use new setting' as shown in Figure 29. You do not have to reboot the device at this point instead of rebooting the device after finishing all the configuration steps. If you do choose to reboot the device at this point you will see Figure 30. By pressing the 'Restart' button at the middle of the screen a rebooting window come out as shown in Figure 31. Refreshing the Internet explore window at the address 10.10.100.254, you will be ask for typing in the username and password again in order to get back to the configuration page again, shown in Figure 32. Both the username and password are 'admin'.

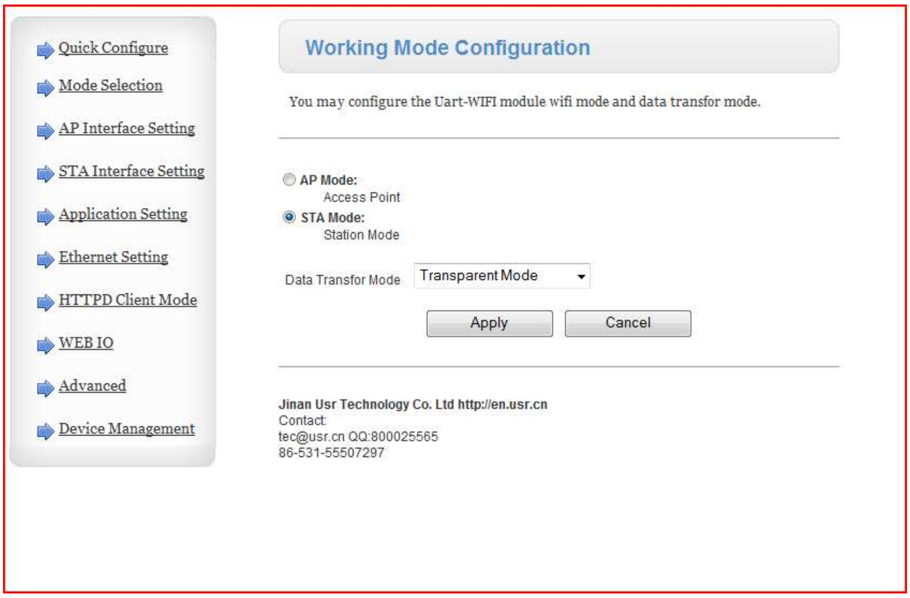

Figure 28. Model Selection

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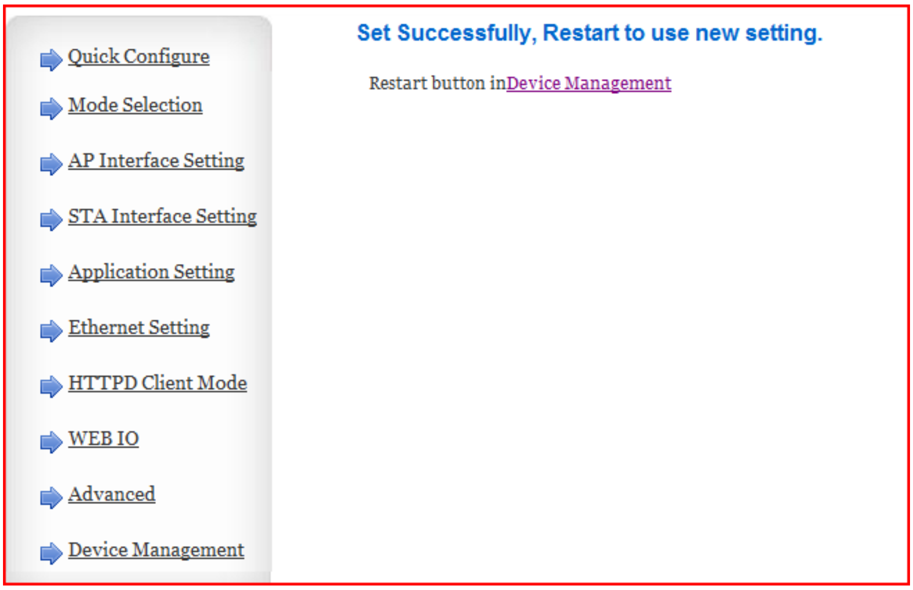

Figure 29. Setting-up successfully

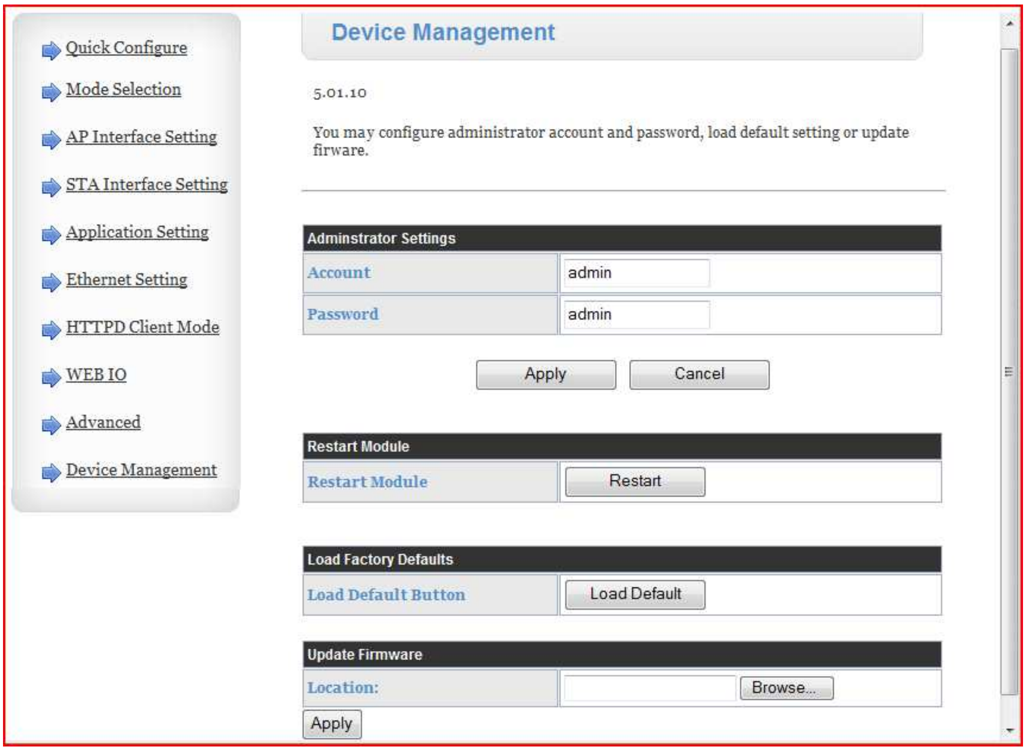

Figure 30. Device management and restarting the module

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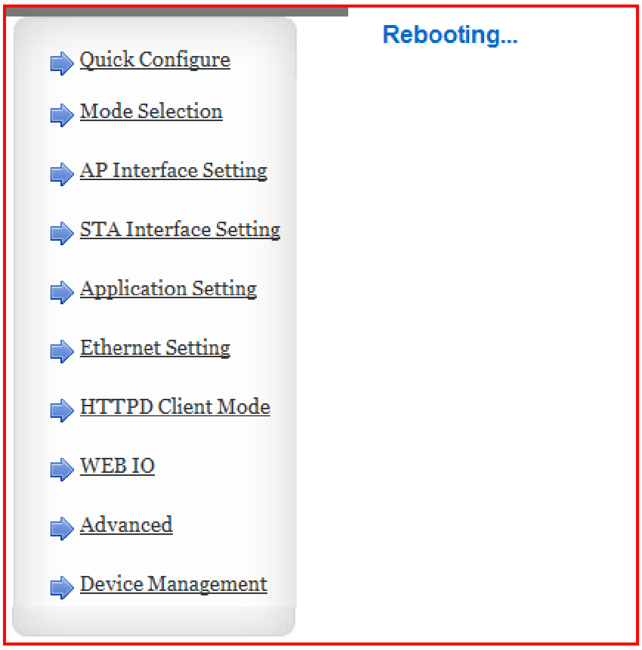

Figure 31. Rebooting the module

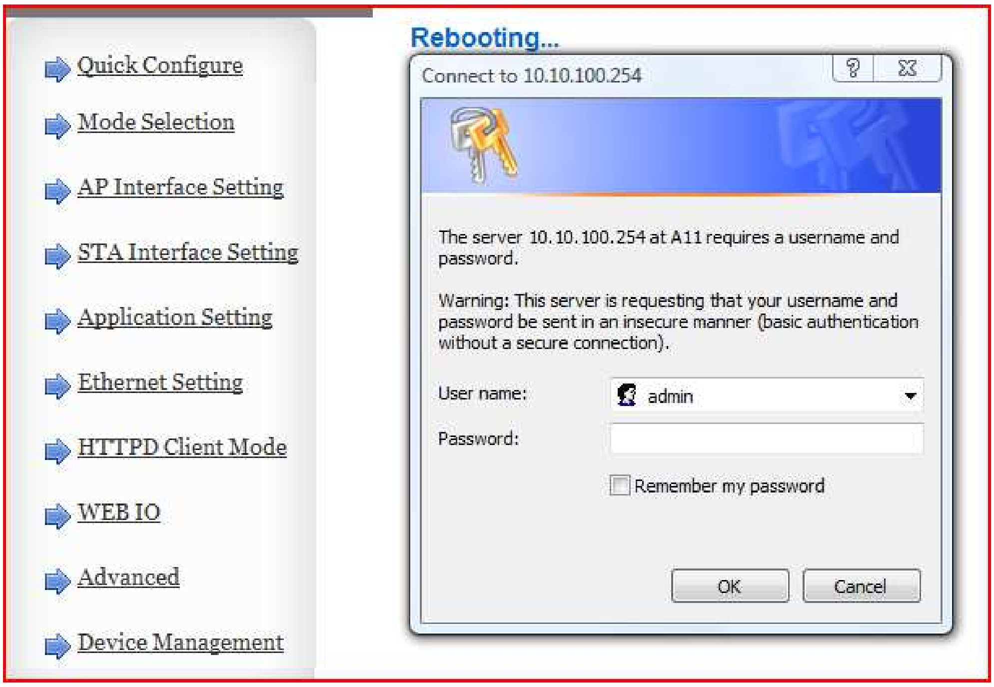

Figure 32. Login page after refreshing the rebooting page

- Step 2. Skip the part of AP Interface setting.
- Step 3. Select 'STA interface setting' to search and connect with the household WiFi router (or wireless Access Point). The search page is shown in Figure 33. By clicking

'Search' button for AP1's SSID you will see a list of all the wireless routers or AP in the vicinity of the 433-to-WiFi gateway. The list is shown in Figure 34. Choose the one which you want to connect to. In this case we choose the first one Aztech557_D49E, then pressing the 'Apply' button at the bottom of the page. You may be asked for typing in the wireless key (Pass Phrase) as shown in Figure 35. The wireless router Aztech557_D49E's password is 'aabbccddee'. You need to ask the household for their wireless key. Press the 'Apply' button again at the bottom of the page. If there is not required network to access, this step can be skipped.

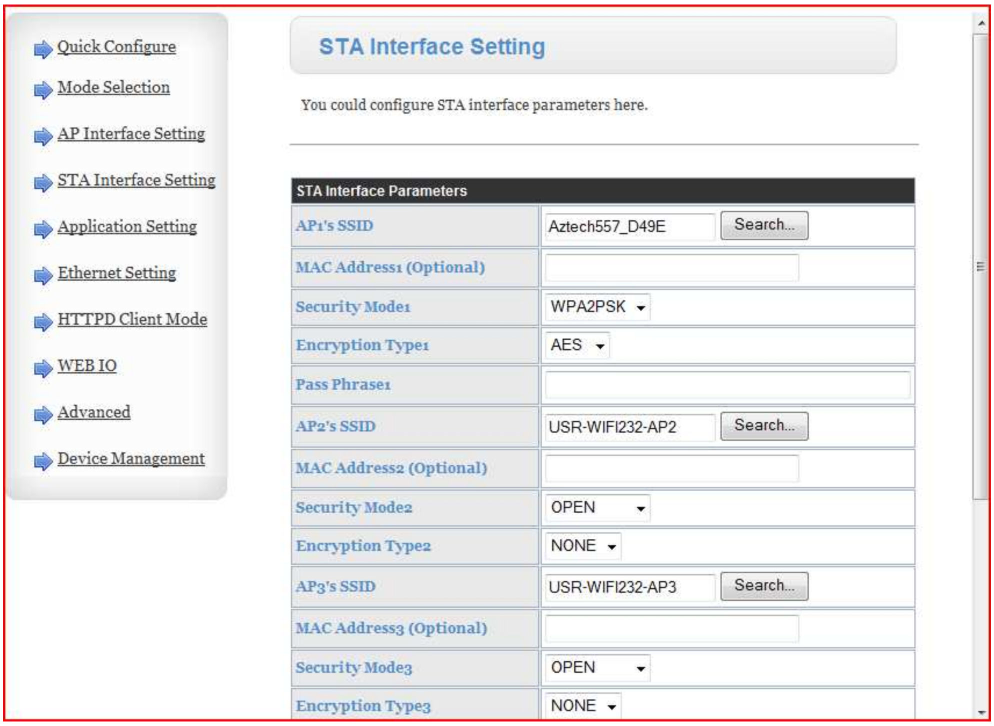

Figure 33. STA (Station) interface setting

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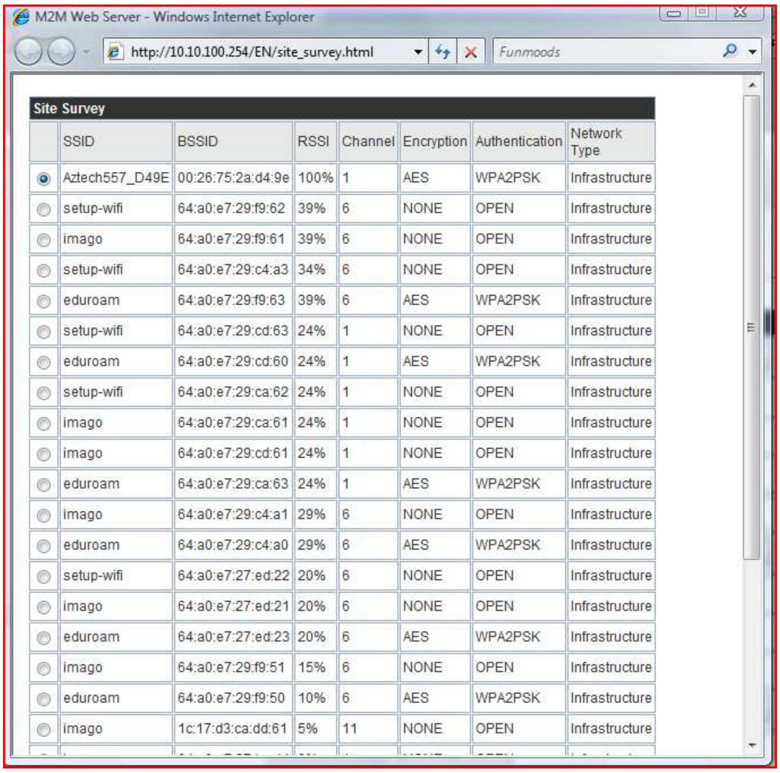

	SSID	BSSID	RSSI	Channel	Encryption	Authentication	Network Type
◉	Aztech557_D49E	00:26:75:2a:d4:9e	100%	1	AES	WPA2PSK	Infrastructure
○	setup-wifi	64:a0:e7:29:f9:62	39%	6	NONE	OPEN	Infrastructure
○	imago	64:a0:e7:29:f9:61	39%	6	NONE	OPEN	Infrastructure
○	setup-wifi	64:a0:e7:29:c4:a3	34%	6	NONE	OPEN	Infrastructure
○	eduroam	64:a0:e7:29:f9:63	39%	6	AES	WPA2PSK	Infrastructure
○	setup-wifi	64:a0:e7:29:cd:63	24%	1	NONE	OPEN	Infrastructure
○	eduroam	64:a0:e7:29:cd:60	24%	1	AES	WPA2PSK	Infrastructure
○	setup-wifi	64:a0:e7:29:ca:62	24%	1	NONE	OPEN	Infrastructure
○	imago	64:a0:e7:29:ca:61	24%	1	NONE	OPEN	Infrastructure
○	imago	64:a0:e7:29:cd:61	24%	1	NONE	OPEN	Infrastructure
○	eduroam	64:a0:e7:29:ca:63	24%	1	AES	WPA2PSK	Infrastructure
○	imago	64:a0:e7:29:c4:a1	29%	6	NONE	OPEN	Infrastructure
○	eduroam	64:a0:e7:29:c4:a0	29%	6	AES	WPA2PSK	Infrastructure
○	setup-wifi	64:a0:e7:27:ed:22	20%	6	NONE	OPEN	Infrastructure
○	imago	64:a0:e7:27:ed:21	20%	6	NONE	OPEN	Infrastructure
○	eduroam	64:a0:e7:27:ed:23	20%	6	AES	WPA2PSK	Infrastructure
○	imago	64:a0:e7:29:f9:51	15%	6	NONE	OPEN	Infrastructure
○	eduroam	64:a0:e7:29:f9:50	10%	6	AES	WPA2PSK	Infrastructure
○	imago	1c:17:d3:ca:dd:61	5%	11	NONE	OPEN	Infrastructure

Figure 34. Selecting the Wi-Fi router at the household

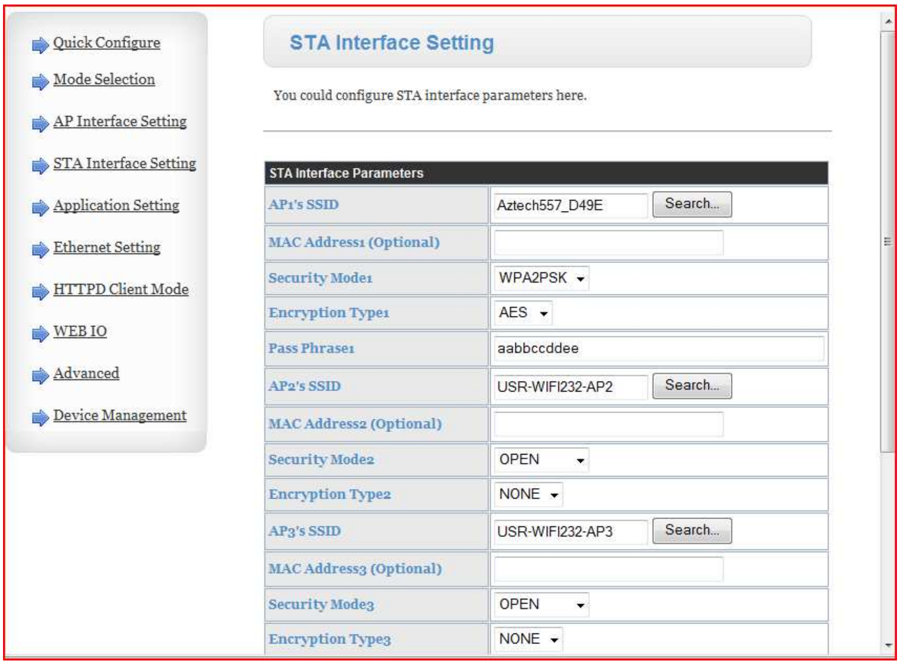

Figure 35. Connecting with the Wi-Fi router at the household

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- Step 4. Select 'Application setting', you will see a configuration page as shown in Figure 36. Move the page to the bottom part, and ignore the 'Uart setting', 'UART AutoFrame setting' and 'device setting'.

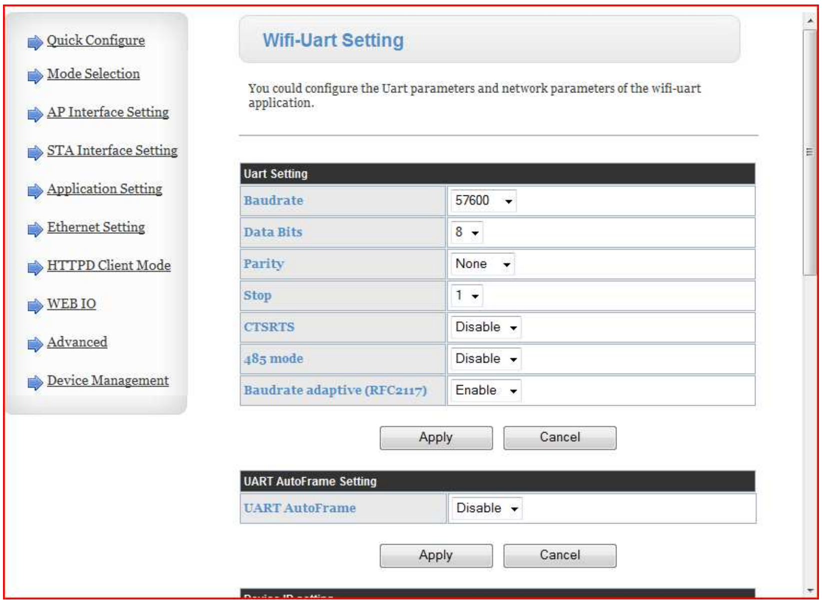

Figure 36. Application setting interface

- Step 5. Network A Setting' mode should be set as 'Server' which will be used for binding with the local mobile devices for future use, and 'Socket B setting' is set as 'on' and type in the port number and server address of the remote server in the field. Press the 'Apply' button to complete the configuration. This is the only place which may need to be re-visited if a remote server has been moved to a different IP address or open a different port.

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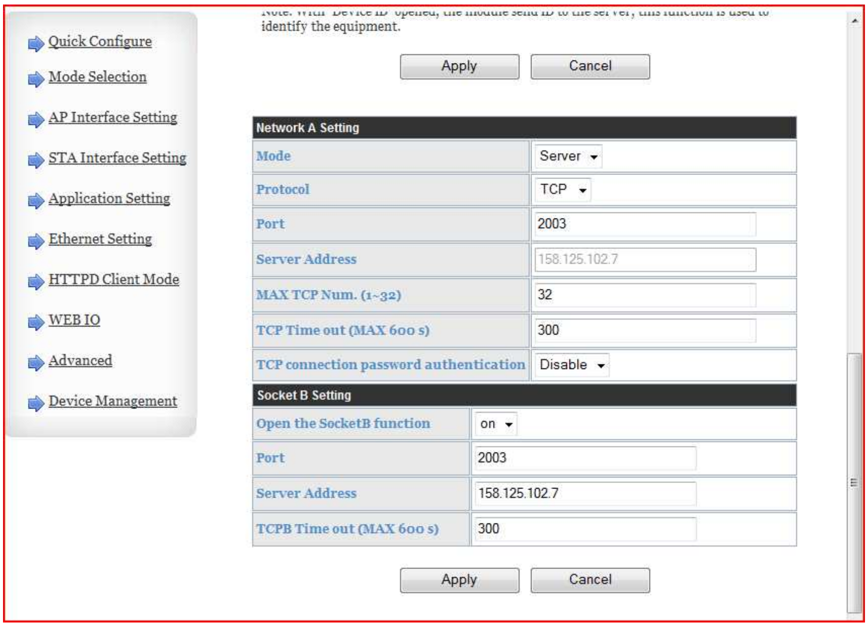

Figure 37. Setting up the remote server

- Step 5. Restart to use the new setting (Figure 38). As this point is the end of the configuration it is recommended to restart the device by clicking the 'Device Management' in the restart window shown in Figure 29 or select 'Device Management' in the main menu and then follow the steps shown in Figures 30, 31, and 32. As shown in Figure 32 you will be asked for typing in the password and username again at the end of this configuration process.

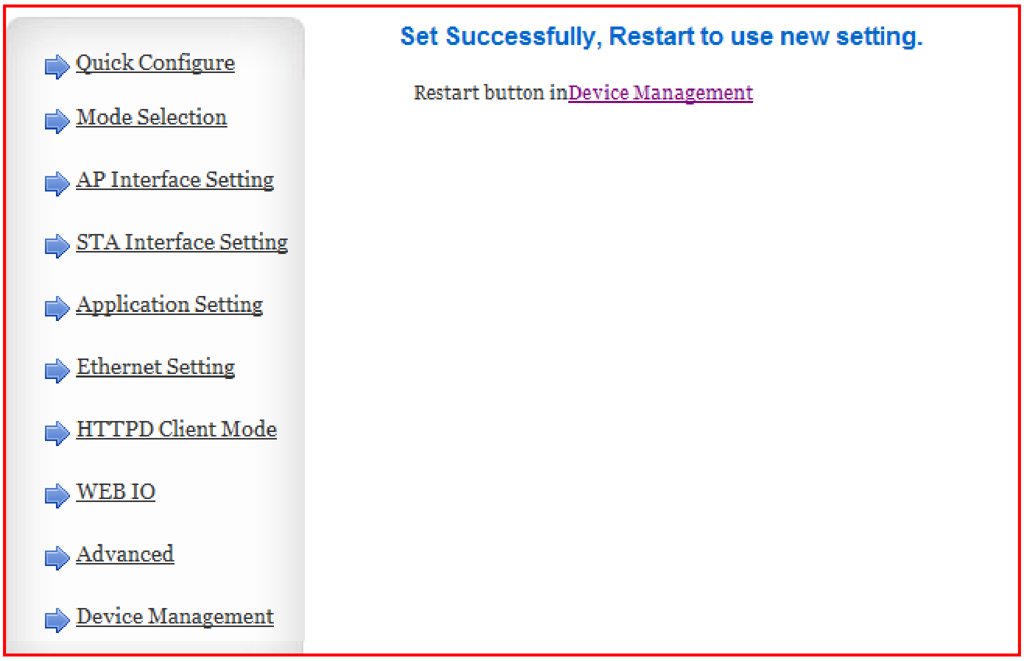

Figure 38. Restart to use new setting

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Appendix 2. Overview of the existing water consumption monitoring solutions

Considering the purpose of use, municipal water meters can be divided into two types: for billing purposes (for use of water suppliers) and for raising the awareness (for personal use of people).

The first group of flow meters allows to collect the data on water use (consumption by client) over a fixed time period for the purposes of water provider. Types of such meters depend on the flow measuring and data collection/transmission technique. For residential applications usually mechanical meters are of use, mostly they include: 1) displacement meters with oscillating piston or nutating disc and 2) velocity meters - single and multi-jet. Data can be read from water meters directly from the meter's display or remotely using a variety of methods but usually based on radio frequency or combined radio-internet / radio-mobile network transmission. Remote readings of the water use depends of the receiving device form which varies from a simple handheld or vehicle mounted device (reading data from the closest flow meters or data collectors) to complex systems of data collectors and access points. The data transmission between flow meter and receiver can be one- or two-directional (called also bidirectional). In the one-directional option flow meter transmits the data continuously with defined intervals. Two-directional option allows "waking" the transmitter and reading data on demand.

The second group of flow meters are aimed at collection of information on water consumption for personal use. Contrary to the flow meters for billing purposes well established in the market, these dedicated for personal use are rare. They are usually less expensive and less accurate than water meters dedicated to water providers. However, they are usually easy to install and provide clear information on water use, sometimes provide water saving hints and wireless communication with personal computers and mobile devices.

Single end-use devices

The main purpose of simple water meters is not to provide exact information on flow for the billing but to raise awareness of the way water is used at our houses and how to reduce the consumption. Below one may find information about simple water meters and their features. The Internet search revealed that only one device is currently available - Amphiro A1. Some more devices found in the Internet are in the prototype stage. Examples of flow meters and their features are presented in following tables:

List of examples:

- Sprav
- Every Drop Counts
- Amphiro A1 / A2 / OEM
- Driblet
- Bware 1.0 / 2.0

Table 6. Description of the Sprav device

Name	Sprav
WWW	http://www.sprav.com https://www.facebook.com/SpravWater http://www.cleveland.com/business/index.ssf/2013/10/cwru_student_company_launches.html#incart_river_default http://www.fastcoexist.com/3020555/fund-this/a-simple-shower-warning-device-that-turns-red-when-youre-in-there-too-long https://www.kickstarter.com/projects/sprav/sprav-turn-your-shower-into-a-smart-shower?ref=email https://www.youtube.com/watch?v=QS_OuGGzx_A
Purchase option / Design stage	No data
Availability of additional information	Registration for updates (done); Online contact form (done)
Price	(predicted 49 USD)
Measured media	Water use; Energy use (heat)
Measuring principles	The device works by sensing water temperature through the pipe and acoustically monitoring the water flow.
Mounting type	Pipe (shower) clamp; No threading;
Application	Shower
Display	No (LED indicator only)

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Name	Sprav
Wireless communication	Bluetooth with dedicated IOS application

Table 7. Description of the Every Drop Counts device

Name	Every Drop Counts
WWW	http://www.igreenspot.com/every-drop-counts-by-ulrik-svenningsen
Purchase option / Design stage	No data
Availability of additional infor-mation	No data
Price	No data
Measured media	Water use; Energy use (heat)
Measuring principles	The device works by sensing water temperature through the pipe and acoustically monitoring the water flow.
Mounting type	Pipe (shower) clamp; No threading;
Application	Pipes
Display	Yes
Wireless communication	Yes

Table 8. Description of the Amphiro A1 device

Name	Amphiro A1
WWW	http://amphiro.com/products/a1/
Purchase option / Design stage	shops in Switzerland and Germany
Availability of additional infor-mation	Manual: http://amphiro.com/wp-content/uploads/2013/04/2013_08_21_a1_manual_EN_V1.pdf Brochure: http://amphiro.com/wp-content/uploads/2013/04/amphiro_a1_flyer_EN.pdf
Price	59,90 EUR in Germany (includes tax and shipment) 54,90 EUR for other EU countries (tax excluded, shipment included)
Measured media	Water use: - flow unit 0,1 L, - flow rate: 5-22 l/min - max pressure: 10 bar - temperature: 5-65 °C - accuracy: 10% at 15 l/s Energy use (energy efficiency classes)
Measuring principles	The device works by sensing water temperature through the pipe and mechanically monitoring the water flow.
Mounting type	1/2" shower head - shower hose connection
Application	Shower (other application possible but not recommended by the pro-ducer)
Display	Yes
Wireless communication	No
IP Protection	65
Power source	No batteries, self (water) powered
Memory	150 shower events
Additional functions	Online data analyses possible at the producer's portal using codes generated after each shower and displayed at the device.

Table 9. Description of the Amphiro A2 device

Name	Amphiro A2
WWW	http://amphiro.com/products/a2/
Purchase option / Design stage	No data
Availability of additional infor-mation	No data
Price	No data
Measured media	Water use: - flow unit 0,1 L, - flow rate: 5-22 l/min - max pressure: 10 bar - temperature: 5-65 °C - accuracy: 10% at 15 l/s Energy use (energy efficiency classes)
Measuring principles	The device works by sensing water temperature through the pipe and mechanically monitoring the water flow.
Mounting type	Shower hose - Smart mounting system
Application	Shower (other application possible but not recommended by the pro-ducer)
Display	Yes
Wireless communication	No
IP Protection	65
Power source	No batteries, self (water) powered
Memory	150 shower events
Additional functions	Online data analyses possible at the producer's portal using codes generated after each shower and displayed at the device.

Table 10. Description of the Amphiro OEM device

Name	Amphiro OEM (module BT40)
WWW	http://amphiro.com/products/oem/
Purchase option / Design stage	No data (probably on request - request sent)
Availability of additional infor-mation	Brochure: http://amphiro.com/wp-content/uploads/2013/04/amphiro_modules_flyer_EN.pdf
Price	No data (probably on request - request sent)
Measured media	Water use: - flow unit 0,1 L, - flow rate: 2,5-22 l/min and more - max. pressure: 1,5MPa (5 MPa on request) - accuracy: 8% at 15 l/s - operation temperature: 0-85°C Temperature
Measuring principles	The device works by sensing water temperature through the pipe and mechanically monitoring the water flow.
Mounting type	A set to be mounted in pipe connection fully configurable depending on needs. Includes: - turbine and coil, - housing (turbine: 58,5 mm length, 30 mm diameter, 1/2" threads), - Temperature sensor (digital and analog output),

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Name	Amphiro OEM (module BT40)
	- power storage unit, - volume and energy sensor (digital output), - LCD and Bluetooth.
Application	Shower (other application possible but not recommended by the pro-ducer)
Display	Yes (as in Amphiro A1)
Wireless communication	Yes (Bluetooth 4.0)
IP Protection	Not specified
Power source	No batteries, self (water) powered
Memory	150 shower events

Table 11. Description of the Driblet device

Name	Driblet
WWW	http://www.driblet.io https://www.facebook.com/driblet.io https://www.youtube.com/watch?v=kr_5e3Sn7I0&feature=youtu.be
Purchase option / Design stage	First beta release in 1Q 2015
Availability of additional infor-mation	E-mail (submitted for updates)
Price	No data (preorder questionnaire)
Measured media	Water use; Temperature
Measuring principles	Not specified
Mounting type	Standard pipes
Application	Not specified
Display	No (visual and sound notifications)
Wireless communication	Yes (WiFi)
IP Protection	Not specified
Power source	No batteries, self (water) powered
Memory	Not specified

Table 12. Description of the Bware 1/2 device

Name	Bware 1/2
WWW	http://daprodukt.com/portfolio/bware-water-meter-saving-water/
Purchase option / Design stage	Preproduction stage
Availability of additional infor-mation	E-mail (updates requested and confirmed by the designer)
Price	No data
Measured media	Water use
Measuring principles	Mechanical measurement
Mounting type	Standard pipes (tap mounted or in pipe connections)
Application	Not specified
Display	Yes: - on device - 1.0 version - on monitoring module - 2.0 version
Wireless communication	Yes: - Wi-Fi in 1.0 version - Bluetooth transmission to the monitoring module (USB in monitoring

Name	Bware 1/2
	module) in 2.0 version
IP Protection	Not specified
Power source	No batteries, self (water) powered
Memory	Not specified

Commercial, 'smart' water consumption monitoring systems

The radio-read systems are a modern and reliable way of data collection from water meters installed at households and industry companies. The radio transmission reduces the risk of human errors, shortens the time of data reading, and so – lowers the costs. The process of data collection does not require a home visit, therefore it is more convenient for everyone. Furthermore, the radio-read system allows for reading in difficult access places or in case of an absence of tenants. This technology allows for a long, maintenance-free operation of devices. Some manufacturers offer two types of wireless radio-read systems, first is a "drive-by" method when readings are carried out using the terminal (e.g. PSION) that has to be operated by a trained employee and second is based on data collectors/hubs that transmit data to the local server/PC either using radio, GPRS or Ethernet. Moreover, a wire-based Mbus technology is also often offered by the European water meters manufacturers. The core of the system is the Mbus terminal that is connected to measuring devices. The communication between parts of the system can be carried out using Ethernet or even cable TV. However, nowadays wire based technologies are combined more often with the wireless radio transmission. Currently there are a few available radio-reading systems that guarantee these two types of data collecting, i.e. either via the terminal manned by the water company employee or data collectors. Below one may find a brief description of commercial solutions that are available in Poland/Europe. The radio-read systems based on data collectors are not very common. Usually water companies cautiously balance the costs of such systems and profits. In majority of cases these utilities do not need such detailed and continuous information about the water consumption and data collected once a month by the employee is sufficient for billing purposes.

Bmeteres – Hydrolink

The company BMETERS Poland has developed an integrated system of media monitoring (metering). It is a radio and wire system that cooperates with a flexible set of the related equipment. BMETERS components allow for reading of water meters, heat meters and heat cost allocators at the same time by means of one data collector set. Due to the remote data reading, all media consumption devices can be checked without the presence of a tenant in the apartment. The basic architecture of the integrated media metering system includes: measuring devices, a radio receiver module, a computer and an appropriate BMETERS software. The system enables: the adjustment to the specific needs and requirements, receiving large amounts of data, the high accuracy of readings and saving time. Radio-reading using MBUS technology can be carried out as:

(i) walk-by/drive-by method directly from measurement devices or micro data collector that is designed to amplify the radio signal in hard-to-reach places. Micro data collectors retransmit data in the most suitable moment (data are stored for 24 hours);

(ii) remote reading via the Internet using an Ethernet hub or a GPRS transmitter. The whole system is powered by a lithium battery, the battery life is 10 years for water meters and 5 years for heat meters. The spatial range is 350 meters. Micro data collector can store 300 records and can be programmed to send data in the user-specified time intervals, in turn the Ethernet hub can collect 500 records, it is configured through optical fibre joint and uses the fixed IP or DHCP addresses.

Brunata

The Brunata company has developed a unique BrunataNet system that allows for a remote reading of water meters. The Brunata Net uses radio transmitters mounted on Brunata devices such as Futura+allocators, radio modules ClickOn Water and pulse counters Futura Signal+. The system allows for sending data directly to the Brunata server. The company Brunata offers to customers four types of configuration: (i) system based on readings by means of hand-held computers (PDA, PSION) and drive-by method that requires the presence of the employee who is equipped with the terminal PSION, (ii) remote reading based on radio communication in the building and RS485 network, (iii)remote reading based on serial Mbus communication and RS 232 network, and finally (iv) remote reading based on the Internet use and broadband (Table 13). In the last option, all collected data can be acquired by the online software called WebMon. This tool enables the instant access to the collected information, data analysis, import and export of files. The radio transmission is unidirectional, the transmitter sends the signal every two minutes as the default value. The battery life is c.a. 10 years.

Table 13. Characteristics of the Brunata water metering systems (source: Brunata)

	System 1	System 2	System 3	System 4
Meter reading by handheld computer	Yes, in or outside the apartment	Yes, by controller box	No	No
Remote reading	No	Yes, radio RS485 via modem	Yes, M-Bus via modem	Yes, RS485 or M-Bus via the Internet
RME95 Heat cost allocators	Yes	Yes, integral radio	No	Yes, integral radio
Water meters	Yes, via pulse counter	Yes, via pulse counter with radio	Yes, HG-meter is pulse counter	Yes, via pulse counter with radio or HG-pulse
Brunata HG Water and energy meters	Yes, via pulse counter	Yes, via pulse counter with radio	Yes, functions as pulse counter	Yes, via M-Bus
SharkyHeat Energy meters	Yes, via pulse counter	Yes, via pulse counter with radio	Yes	M-Bus / RS232
RayHeat Energy meters	Yes, via pulse counter	Yes, via pulse counter with radio	Yes, if no water meters are installed	M-Bus / RS232
Electricity and gas meters	Yes, via pulse counter	Yes, via pulse counter with radio	Yes, HG-meter is pulse counter	Yes, via pulse counter with radio or HG-pulse
Reading system	None	BrunataMonitor	Brunata M-Com	Brunata WebMon via the Internet

Ista

The Ista company offers the bidirectional Mbus data transmission that enables recording and transmitting of data from heat, water meters and pulse generators. Data is read by the Mbus LC 250 terminal that can manage up to 250 devices, and by using the special BusSwitcher that allows to connect 2 000 devices. The system consists of: Mbus modules for water meters, the Pulsonic device allowing for a connection of pulse generators with the Mbus device, the Mbus LC 250 terminal, the GSM modem, and optionally the Bus Switcher. Devices that are parts of the system have unique Mbus addresses, it simplifies the data analysis and the maintenance of the system. Moreover the Ista company has in the offer the radio-transmission system called Symphonic 3. It can be implemented as a "walk-by" system or a

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web-based system. The first solution requires the portable computer PDA (personal digital assistant) equipped with the MGW (media gateway) module and the complete list of devices that should be checked. The PDA device sends the request to the enlisted devices that have to decode it and send the requested data back to the PDA. Subsequently, the PDA computer decodes the package and can store it in the memory. Afterwards, all data is sent via the Ethernet to the billing system. The second option involves the net of sensors, it is fully automated system that is managed by a central administrative-communication unit Memonic 3 equipped with the GSM/GPRS modem. It configures the sensors in a form of a tree (subnet), determines the reading schedule and transmits all data collected by sensors to the server. After receiving data is available to customers via the web portal ista24.pl.

Mirometr/Diehl

The Mirometr company offers two types of the radio-read systems: drive-by and long-range stationary (Izar R4). Both systems rely on the one-way radio link (868 MHz frequency). In case of the first method, data can be sent every 8 seconds, whilst the stationary option offers intervals of 15 minutes. The drive-by readings can be carried out at maximum speed of 30 km/h, currently there are c.a. 270 000 water meters in Poland that are checked in this way. The terminal used for data collecting is equipped with the Bluetooth head allowing for a longer operation time and a wider range. In case of the stationary system, one data collector may receive data from 10 000 media meters. The stationary systems (Izar Rc and Izar R4) are very recent, both were tested in 2013 in two cities in France.

Table 14. Technical characteristics of the Izar systems (source: Mirometr/Diehl Germany)

		IZAR RC i R4
Communication protocol		PRIOS
Frequency	MHz	868.95 or 434.47 (R3 mode) and 868.30 or 433.42 (R4 mode)
Modulation		FSK
Transmission power	mW	16
Transmission mode		Unidirectional
Radio range		Up to 500 m depending on the environment
Approval		EN 300 220, CE RTTE
Power supply		Lithium 3.6 V
Typical life		up to 15 years*

Itron

The Itron company offers a complex service regarding media monitoring. The water use consumption can be monitored by the Mbus central terminal and the network of meters. Moreover, the Itron has in the offer the radio-read system that can be performed as a "drive-by" or stationary solution. The first type of monitoring service is currently applied by the Regional Water Supply and Sanitation Company in Sosnowiec and it is briefly described in section 2.1 of this document. This system may be transformed into the stationary network by replacing regular radio modules with the CybleEverblue and by adding collector/access points. The latter sends collected data using the GPRS technology to the FTP server. The general scheme of this method is presented in Figure 39.

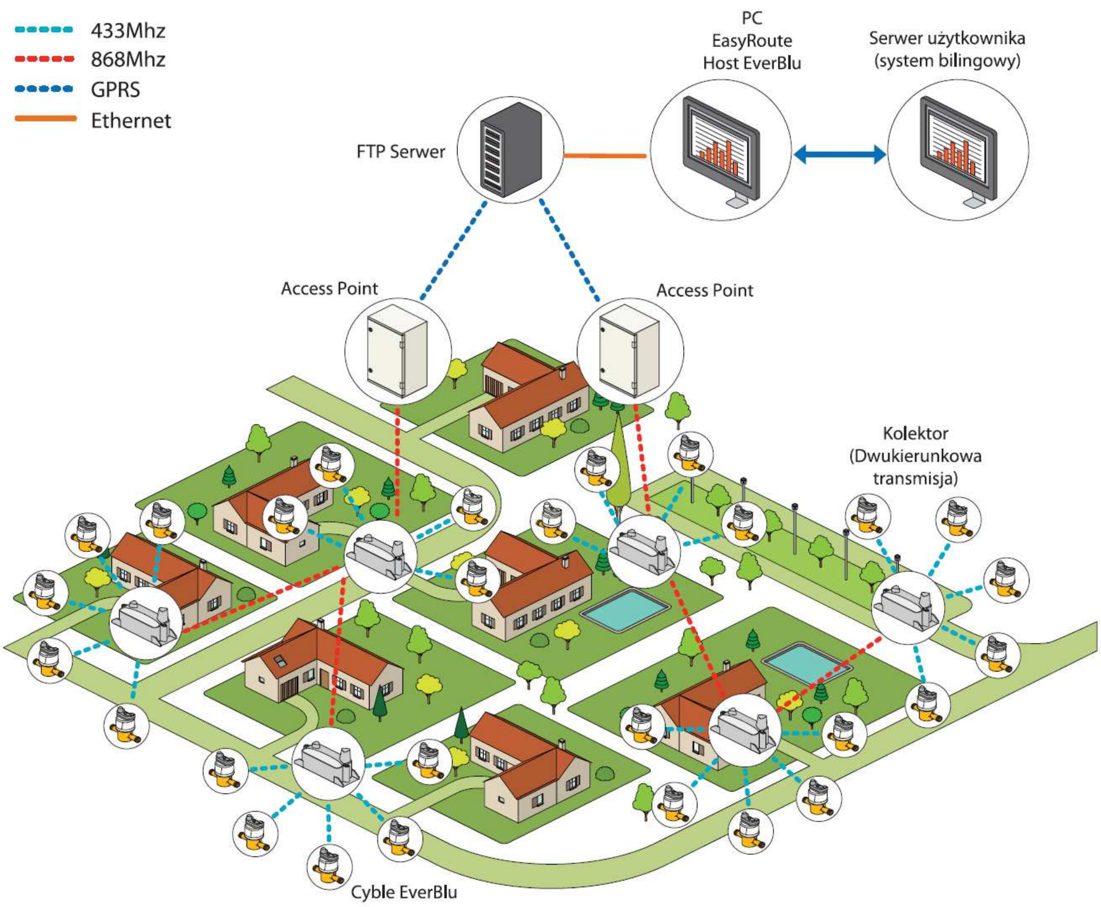

Figure 39. The EverBlue stationary system (source: Itron)

The stationary system was primarily considered as an alternative way to collect the municipal water consumption data. However, it turned out that it was not widely tested. Further-

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more, due to necessity of installation of many access points (the spatial range in a residential area is dozens meters) it is relatively expensive. In addition, sending the data from access points/data collectors to the server is via the GPRS transmitter instead of the preferred Internet broadband connection.

Apator Powogaz

Apator Powogaz is one of the largest manufacturers of media meters in Poland and Europe. The company offers reliable and ready-to-use radio-read metering systems. These systems are based on the wireless Mbus technology that enables the integration of devices made by other manufacturers. The system can function as a walk-by or stationary. In both cases, it guarantees the data reading in case of difficult access and at any time. The radio-read modules assure low power consumption and years of free-maintenance operation.

The walk-by method is carried out by an employee (collector) equipped with the PDA computer. The full system consists of: radio modules, terminal, radio module Bluetooth/Mbus and the software – Inkasent. The data readings are performed from the outside of the apartment so owner/tenants do not have to be at home during the collector's visit. In turn the stationary system consists of water meters with the special modules, re-transmitters, data collector and the dedicated software. Radio-, Ethernet or GPRS modems are embedded in the data collectors. The stationary system is suitable for 24/7 monitoring of media usage or in case of a long distance water supply system. Figure 40 presents the scheme of connections between devices for the walk-by and stationary metering systems.

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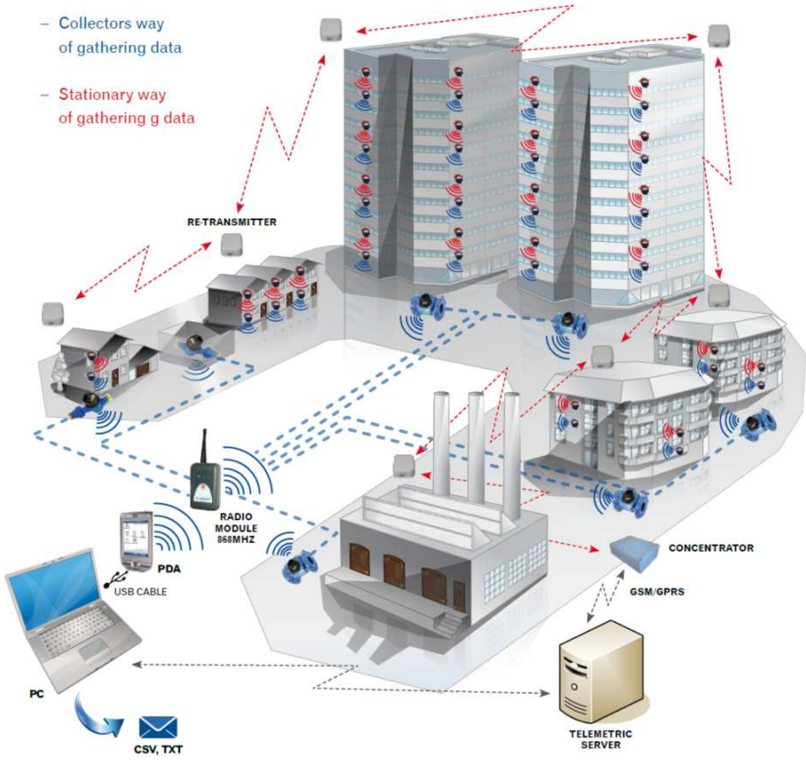

Figure 40. The Apator Powogaz stationary, radio-read water use monitoring system (source: Apator Powogaz)

The system offered by the Apator Powogaz company has been selected as an alternative to the novel, wireless system designed in the framework of WP2.

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Appendix 3. Technical description of the alternative (commercial) water consumption monitoring system installed in 10 households in Sosnowiec, Poland

ELEMENTS OF THE AMR RADIO SYSTEM

The presented AMR system functions on the basis of the Apator Powogaz product's offer, of which the following water meters consist: apartment type JS, JM, WS and WM, housing type JS, WS WM: and industrial type MWN, MP and JS class C.

THE FOLLOWING APPLIANCES REALIZE REMOTE DATA READING:

- In the collector's version- radio modules, terminal, radio module Bluetooth/WMBUS and software. The Inkasent software is available on PC and PDA.
- In the stationary version- radio modules, re-transmitters, concentrators with communication modems and WMBUS Reader software available on PC.

EXAMPLE OF RADIO MODULE USAGE

Apartment water meter
JS Smart+ type

Industrial water meter
WMN type

ELEMENTS OF THE COLLECTOR'S DATA READINGS

SMART TOP RADIO MODULE

Smart Top radio module is build on the basis of the newest microprocessor system and is used to the wireless data transmission of the measuring Smart water meters, at distance up to 300m in the open space. The network works on the radio band of 868MHz and the installed battery can last up to 12 years of constant work. In the appliance was implemented a communication protocol WMBUS compatible with the PN-EN 13757 norm in the range of the wireless water meters readings, allowing for two-way data transmission.

THE MODULE HAS:

- The system of optical sensors allowing identification of the current water flow and by taking into consideration the backward flow it gives complete conformity with the indication of the counter.
- The reading of data is fully resistant to any external magnetic field interference
- Possibility of manual reading using a PDA terminal or using stationary system with automatic reading
- Possibility of signalling of the following alarms:
  - Module take-off alarm: signalling disjoining of the module and the water meter- the following data are registered: date and time of disconnection as well as total time of disconnection,
  - Backward flow alarm- detection of the backward flow. The following data are registered: sum of the water volume flown backward with data and time of the first alarm,
  - Magnet usage alarm- signalling magnet usage to the water meter. Date and time of the first alarm and the summary time of the magnet influence are registered.
- Possibility to transmit the following data:
  - Maximum flow signalisation – detection of the maximum flow (over the amount defined by the user). Date and time of the first incident are registered.
  - Leak signalisation – leak detection, which is defined as constant, continuous flow, in time defined by the user (e.g. 120 min). Date and time of the first incident are registered.
  - In AT-WMBUS-08 also the full leak time is registered
  - State skipping signalisation - the state of the reflective shield with the excessive flow in the water meter has been skipped,
  - Battery running-down signalisation - signalises a run-down battery on the module
  - Signalization of a high level of light- detection of a high light level on the optical elements (tamper attempt)
  - Minimal flow signalisation (AT-WMBUS-08)- detection of the flow below defined amount. Date and time of the first incident are registered.

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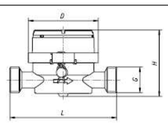
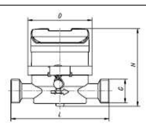
Table 1. TECHNICAL SPECIFICATION

Type of the module	AT-WMBUS-01 or 07 module	AT-WMBUS-04 module	AT-WMBUS-08 module
Application	Direct installation on the counting mechanism on the following water meters: - Apartments (DN 15-20mm) JS-01 and 02 type - Housing (DN 25÷40mm) JS type - Industrial (DN 40÷500mm) MWN; MP; JS class. C; MK; MWN/JS type	External radio module installed close to the water meter, as-signed to cooperation with the water meters equipped with the pulse transmitters (NK and NO) e.g. WS; WM	Installed directly on the counting mechanism on the apartment water meter (for hot and cold water)- JS-02 type (Smart+)
Physical characteristics	h = 44; ø = 65.5 [mm]	90 x 74.5 x 41.4 [mm]	h = 26.5; ø = 65.5 [mm]
Protection rating	IP 65	IP 65	IP 68
Weight	0,06[kg]	0,18[kg]	0,033[kg]
Increase of height of the water meter after install-ing the H module	35,8[mm]	N/A	18,5[mm]
Example:			
	JS-02	-	JS-02 Smart+
Height of the water me-ter with the module	 H=105mm	H = the catalogue height of the water meter with the transmitter NK or NO	 H=87mm

RADIO COMMUNICATION

The way of counting impulses	reflective Transoptor
Transmission speed	100 k bit/s
Data protocol format	Wireless M-Bus
Programmed logger	Configuration of the initial state and the ID of the water meter and frequency of transmitting
Data storage	Actual consumption rate, of the last 12 months of merit
Tryb pracy T1 / T2	Tryb pracy T1 / T2
Frequency range	868,95 MHz
Adjacent-channel interval	50 kHz
Instability of the frequency	< ±2.5 kHz
Transmission mode	half-duplex
T1 transmitter	
Power output	10 mW / 50 Ω
Stability of the output power level	+1 dB / -3 dB
Adjacent-channel power	according to ET S 300 220-1
Radiation interference	according to ET S 300 220-3
T2 receiver	
Sensitivity	-105 dBm (BER < 10 E-3)
Dampen of the interference adjacent-channel	> -12 dB
Selectivity	> 45 dB
Dampen of the radio inter-modulated noises	> 45 dB

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ELEMENTS OF THE STATIONARY DATA READING

SMART TOP RADIO MODULE (like in the collector data reading- page 6)

RE-TRANSMITTER

Re-transmitter of the radio signal is an appliance put between radio modules and the concentrator, for broadening the wireless network range. Increase the max allowed distance between those appliances. The re-transmitter works on the basis of renewed broadcast of the received WMBUS border from the measuring appliances from different media, e.g. apartment water meter module AT-WMBUS-01 type. Application of the re-transmitter allows for greater range of data reading.

RE-TRANSMITTER FUNCTIONS:

- Supplied from the230V power network
- Works autonomously - activation consist in switching on the power supply unit only
- Possibility to extend the transmission route (max 8 re-transmitters)
- Integration of the aerial inside the appliance housing.

Table 4. TECHNICAL SPECIFICATION OF THE RE-TRANSMITTER

Power supply	
Power supply	From the 230V network, galvanic insulation with a help of the transformer
Power consumption	<1W
RF interface- parameters according to EN 13757-4	
Device works:	T1 mode with the 868.95MHz frequency
Power transmitting	To 25mW (according to the ISM limitations)
T1 transmit range	Open area up to 500m In buildings it depends on the construction and localization
Sensitivity of the receiver	Better than - 100dBm
Mechanical specification	
Dimensions	70 x 66 x 44 mm
Protection rating	IP68
Installation	On wall
Mass	0.19kg
Surrounding environment specification	
Work temperature	0 °C to 55 °C
Purpose	To work in closed rooms

CONCENTRATOR

Concentrator is used to gather data transmitted from the radio modules of measuring devices or re-transmitters and transferring them for further analysis throughout the GSM/GPRS network, Internet or radio modem to telemetric server for further analyses. Cooperation of the concentrator with the re-transmitter contributes to make the network with more appliances for reading. The concentrator is usually placed in the place with a large concentration of radio modules installed.

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CONCENTRATOR FUNCTIONS

- Receiving and saving of the radio frames in WMBUS standard from the specific devices (max 1900 devices)
- Receiving of the retransmitted radio frames
- Connecting at a very particular time (every hour, every day or every month) with FTP server defined by user, by the GPRS protocol and saving data to file
- Configuration of the concentrator by file saved on the FTP server
- Servicing and configuration by the RS-485 or RS-232 interface
- Antenna integrated inside the concentrator's casing

Table 5. TECHNICAL SPECIFICATIONS OF THE CONCENTRATOR

Power supply	
Power supply	Power supply 230V, galvanic isolation by transformer or 5÷9 V DC (1A) charger
Power consumption	< 1 VA while receiving data < 20 VA while working in the GSM network
Communication	
Data storage memory	Max 1900 radio addresses
RF antenna	Built inside the device's housing
GSM antenna	Built inside the device's housing
RF interface- parameters according to EN 13757-4	
GSM module	Four-way 850/900/1800/1900 MHz Class 4 (2W) 850/900 MHz Class 1 (1W) 1800/1900 MHz Sensitivity- 107 dBm 850/900 MHz Sensitivity- 106 dBm 1800/1900 MHz
GPRS data transfer	"download"- depends on the size of configuration file "upload"- 258B x amount of the radio addresses
Receiver sensitivity	More than - 100dBm
Mechanical specification	
Dimensions	180 x 126 x 55 mm (typ A) 165 x 126 x 80 mm(typ B)
Protection rating	IP 68
Installation	On wall (A type) On the pole with diameter up to 50mm (B type)
Weight	< 0,5 kg
Environment specification	
Work temperature	0°C do 55°C

TYP A

TYP B

WMBUSREADER SOFTWARE FOR PC

WMSBUS Reader software can be installed on the PC computers with Windows software (XP, Vista, 7). Thanks to applied applications it allows to analyze and visualize readings and managing them from any administration desktop.

THE SOFTWARE ALLOWS TO:

- Communicate with the database- reading of information gathered during the radio transmission from all buildings (stairways, apartments and devices), all concentrators etc.
- Configure of the concentrator.
- Making reports concerning balancing of water consumption.
- Making visualizations and diagnosing of system work.