IOT CLOUD SOLUTION FOR EFFICIENT ELECTRICITY CONSUMPTION

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ABSTRACT

The solution proposed here aims to optimize the electricity costs of a household, based on time-of-use rates, by reprogramming and automating appliances and devices that are major electricity consumers. It also offers real-time monitoring of the power usage, while providing predictive analyses and optimization solutions based on the collected data, to help the household occupants in making consumption-related decisions. A cloud platform is going to be used to connect home appliances, systems, sensors, and smart meter. The platform will combine the services offered by the Azure IoT Suite, chosen because it facilitates the rapid development of IoT solutions and provides several preconfigured solutions for quickly developing IoT systems. The solution is based on collecting disparate data from sensors and home appliances and processing and analyzing them, in order to assist the customer in identifying inefficiencies, setting specific sustainability goals, and balancing between the budget and the desired comfort.

KEYWORDS: *Internet of Things (IoT), IoT cloud solution, Azure IoT Suite, smart homes, residential electricity management.*

1. INTRODUCTION

The intelligent IoT-based solutions provide the technological means to reduce resource consumption, while also diminishing the impact on the deployed operations. The real-time access to energy consumption information (but also of other resources such as water, gas, etc.), allow making more coherent decisions regarding the resource allocation, such as adjusting or automating operating schedules of various equipment. By implementing

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advanced analysis, presentation and data visualization features, these IoT solutions help to identify inefficiencies while offering consumption-related suggestions.

The main objective of our IoT solution is to reduce the electricity consumption of a household by monitoring and automating the appliances and home systems that have high impact on the electricity usage, such as: boiler / water heater, washing machine, dryer, dishwasher, HVAC system (heating, ventilation, air conditioning system).

The solution will collect telemetry data of the power usage of individual appliances and analyze them using forecasting algorithms, in order to assist the user in making the most efficient decisions. The devices will send the measured data and the integrated cloud services will store and process them, will trigger alarms or notifications, or take actions when the measured values exceed certain thresholds. Furthermore, the recorded data will be used to analyze the consumption history over a time frame, so that it can predict the electricity consumption dataset for each of the individual appliances, estimate the monthly electricity usage, alert the user when exceeding a predefined consumption level, and eventually provide suggestions to reduce it.

Out of the existing IoT platforms, for the present solution we have chosen Azure IoT Suite, since it provides a wide range of functionalities to collect data from devices, analyze data streams, store and query large data sets, display real-time and historical data, manage devices, make complex analyses and predictions [5], and also allows for the rapid development of IoT solutions starting from some preconfigured examples.

2. THE AZURE IOT SUITE SERVICES FOR THE PROPOSED SOLUTION

Azure IoT Suite is a platform as a service (PaaS) that provides all resources needed to collect and manage the data from different devices, and also to analyze, interpret, process, manipulate, and use those data according to the user's requirements [6].

The preconfigured solutions can be used as starting point in developing own personalized IoT solutions. They guarantee easier deployment by quickly connecting one's own devices and appliances. They can be effortlessly scaled from several sensors to millions of heterogeneous devices connected at the same time. The devices will be included in the same solution, and the data they provide will be collected, analyzed, processed, and displayed using cloud services. The Remote Monitoring preconfigured solution is used as a basis for designing our proposed system.

A similar Azure IoT based solution was proposed in [1], where the solution of a smart city platform for automated waste collection was presented.

In a simplified description, the solution considered here is structured into three important phases: first, the devices (smart meter, sensors, systems and appliances) must be connected to the back-end system; next, the data received from these devices must be continuously gathered and collected into the cloud, and then processed and analyzed in order to provide predictive and streamlined consumption solutions.

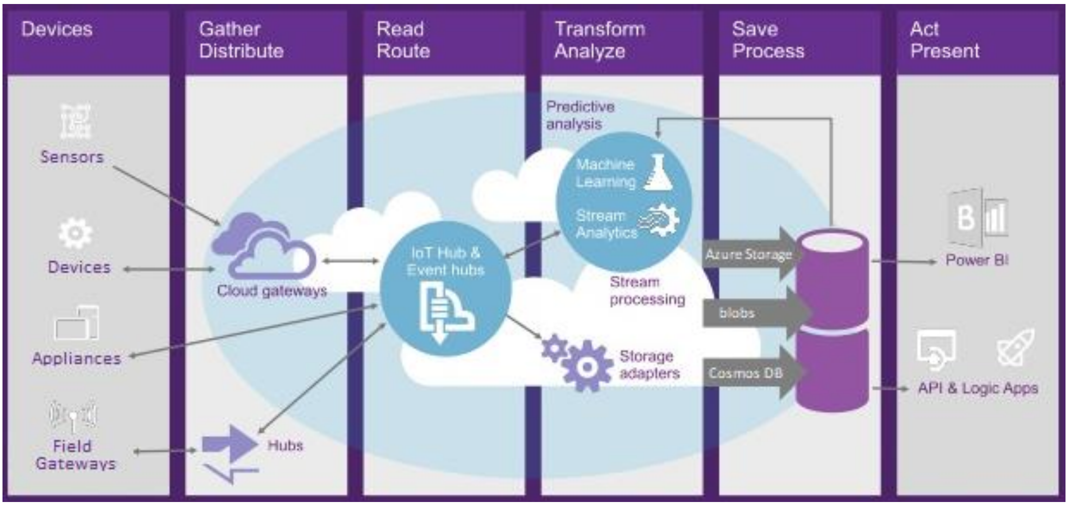

Figure 1. Azure cloud services in the proposed solution
(Source: adapted from [10])

The solution will receive the data collected from the devices through the IoT Hub. All devices will be connected either directly or indirectly via a gateway.

Next, the telemetry data received from the devices will be processed by Stream Analytics and redirected towards Azure Storage to be stored in blobs or to Power BI for visualization. The data are also analyzed for detecting events: the recorded telemetry values are compared to certain thresholds, and if these thresholds are exceeded, alerts and notifications will be triggered and transmitted to the Event Hub to decide on the appropriate action.

Stream Analytics also processes information messages containing device metadata, status data, or devices' responses to commands. The metadata are sent to be stored in the Cosmos DB database, while the status data are redirected to Azure Storage for being stored in special blobs containing status reports, and also to the Event Hub in case a change in status was detected or an event was triggered.

The advanced analysis, estimation, and prediction operations will be done by the Azure Machine Learning module.

The Power BI service will be used for interactive data visualization and it will guarantee displaying relevant information about the entire system. It can present real-time and historical information to the user, based on the telemetry data stored in blobs; it can display information regarding the device status or configuration, existing notifications and alerts. The dashboard will provide functionalities for managing the entire system, allowing the user to perform various actions, adjust thresholds values, send commands to devices, schedule automatic jobs. The various reports and other types of documents that will be created will also be stored into blobs. The form of presentation will use web pages and mobile application.

3. THE CATEGORIES OF DEVICES THAT WILL BE CONNECTED TO THE IOT SOLUTION

The following categories of devices will be included in the present solution. Some of these devices are mainly used for providing data to the IoT system for analysis and prediction, while others can be programmed and automatized:

- Smart meter. It provides data about the overall power consumption of the household, that will be used for analyzing usage behavior, establishing consumption patterns, estimating future electricity usage, suggesting a better energy price plan.
- Appliances and systems with high power consumption. Some of them can be reprogrammed to function outside peak hours: washing machine, dryer, dishwasher, boiler, water heater; others can be programmed and automatized for a more efficient electricity usage: HVAC system.
- Smart plugs and outlets. These are devices for monitoring electricity consumption in single appliances, but also for controlling and scheduling them. They usually can be programmed to turn appliances on and off according to an energy saving schedule. They will be used for connecting those appliances that do not have built-in smart capabilities (older technology, less smart appliances), which means that the present solution can also monitor and optimize the electricity consumption for older appliances.
- Ambient sensors. Are low-power sensors for providing information about the household environment: temperature, humidity, pressure, CO_2 concentration. The IoT solution can use inexpensive individual sensors for measuring these environmental parameters, but nowadays integrated smart sensors are available that combine multiple sensing and measuring functions in a single package and are able to evaluate the air quality, as well.
- Occupancy sensors. They have a big impact in reducing energy consumption and are frequently used for controlling the ambient light depending on room occupancy; but for the purpose of the present solution the data they provide will be used for controlling and automating heating, air conditioning, and ventilation functions.

The number of sensors has not been established, but ideally it should include ambient and occupancy sensors for each room of the household. The more devices connected to the back-end solution, the more information is gathered, which allows for better electricity consumption management and prediction.

4. DEVICES CONNECTIVITY AND THE IOT HUB

Any IoT system is based on reliable and secure bidirectional communication between connected devices and the back-end solution. Azure IoT Suite provides the tools to build an internal infrastructure that can handle tens or hundreds of heterogeneous IoT devices [5].

The sensors, home appliances and systems will be connected to the cloud solution via the IoT Hub, this service representing the cloud main entry point. All devices will be connected either directly or indirectly via a gateway, depending on their specific characteristics and the protocols they support.

Therefore, IP-capable devices can be directly connected if they support the protocols accepted by the IoT Hub (HTTPS, MQTT, AMQP). If some devices only support specific custom protocols, or for security reasons, they will be connected via a cloud-gateway. The cloud-gateway provides benchmarks for device connectivity and facilitates bidirectional communication with the back-end system. If a device cannot use any of the communication protocols supported by the cloud-gateway, it can be connected via an intermediate gateway. For example, sensors and other devices that do not support Internet connectivity will be connected to a field-gateway through specific protocols (ZigBee, Bluetooth), the field-gateway having to translate the communication protocols and ensure cloud connectivity.

The communication is bidirectional, meaning that the IoT Hub allows both device-to-cloud and cloud-to-device messaging. It also implements device management features such as the ability to configure, restart, reset, or upgrade the firmware of some of the devices connected to the hub.

IoT Hub is the central element of IoT Suite. This is a fully managed service through which devices connect to the cloud solution. It acts as a gateway to the cloud and other IoT Suite services. The IoT Hub service enables the back-end solution to receive telemetry data from sensors and home appliances, it routes device data to an event processor, it sends device-to-cloud messages to certain services, and cloud-to-device messages to certain devices, it provides messaging capabilities, allowing reliable and secure communications between IoT devices and the back-end solution [7].

For the solution we have designed, the IoT Hub will provide the following functionalities:

- Sensors and devices management. Ensures the storage, synchronization, and querying of device metadata and status information. The twin devices (JSON documents) associated to the real ones, keep track of their metadata, status, and configuration.
- Telemetry data management. Telemetry data received from sensors, appliances and smart meter, are sent to be stored in blobs, to be processed and analyzed by Stream Analytics, or to be displayed through Power BI.
- Monitoring devices connectivity. It keeps detailed logs of devices logging events, identifying connectivity issues, or devices that reject cloud messages.
- Messages management and routing. IoT Hub is the service that deals with managing, routing, and storing messages, controlling where (to which service) to send messages from devices, and vice versa, to which particular device to send the messages from the cloud.

5. DATA COLLECTED BY THE CURRENT SOLUTION

For our designed IoT solution, the following cloud entries are expected:

- Telemetry data from the smart meter, will provide information regarding the total electricity consumption of the household; the values might de differentiated for on-peak and off-peak periods, depending if the energy supply contract includes different time-of-use plans.
- Telemetry data from smart devices. For example, a smart heating or cooling system could send the electricity consumption information directly to the IoT Hub. Furthermore, these systems and appliances might implement smart edge functionalities with different processing capabilities, such as providing suggestions for more efficient consumption or increased comfort.
- Telemetry data from electricity consumption sensors. They will provide information about the power consumption of each individual appliance in the household. For instance, if a washing machine or boiler does not have smart capabilities, then smart plugs and outlets can be used to monitor their power consumption.
- Telemetry data from different ambient sensors: sensors for measuring temperature, pressure, humidity, CO_2 concentration, will be installed in each room. These parameters have an important impact on the comfort of the household occupants. The information they provide will be used to optimize or automate the HVAC system.
- Telemetry data from occupancy sensors. They provide information on the occupancy of each room; for the present solution, this information will be used to make decisions about optimizing the HVAC system. For example, if it is found that a room has not been occupied for the last hour, the IoT solution may cause the HVAC system to switch to a minimum functioning mode; when the camera is occupied again, it can return to the comfort regime.
- Metadata and status data from the devices, that describe the device features, containing relevant device information, configuration, and status information.

The data received through the IoT Hub will be forwarded to the Azure Storage service to be stored in blobs or in the Cosmos DB database, to be processed and analyzed by Stream Analytics in order to report events or to display them through Power BI. For forecasting analysis, the data will further be processed by the Machine Learning module that uses our developed method compiled as a Python package, for forecasting the individual electricity consumption of the appliances. Device metadata will be stored in the Cosmos DB database, while telemetry data collected from sensors and devices and data containing status information will be stored in blobs.

Besides the data collected from devices, the IoT solution needs additional information. For this reason, a module for inputting external data will be implemented that will include the following information:

- Information regarding the users' behavior: their daily program, comfort preferences (desired temperature / humidity regime), automation preferences, etc.; these are very important not only for the optimal functioning of the system, but also for establishing behavioral patterns.
- External environmental conditions, since they affect energy consumption. The best example is in case of extreme temperatures, when air conditioning or heating systems run at maximum capacity. Therefore, including information from weather forecasts helps to more accurately predict the behavior of the system, and can also provide some suggestion of efficiency. The weather information will be retrieved based on a subscription to a forecast provider.
- General information on the electricity supply contract, the current supplier's and other suppliers' price plans. These will be used in calculations to estimate the value of the electricity bill, but also to provide suggestions for better choices of tariffs or even suppliers.

6. DATA ANALYSIS, PROCESSING AND STORAGE

The service that performs the real-time processing and analytical calculations on the streaming data received from the sensors and devices or from other sources, is Stream Analytics. It is used to process incoming messages from devices and to send them to other services. It will examine the incoming streams and, depending on their characteristics, will decide on the actions to be performed, such as: generating alerts and notifications and redirect them to the Event Hub, sending information to reporting and viewing tools like Power BI, or storing data for further investigation and processing into blobs or the Cosmos DB database [8].

Regarding the categories of data that will be aggregated and processed by Stream Analytics, the present solution will have:

- Telemetry data. These are values provided by the devices, such as: ambient information (values for temperature, air pressure, humidity, CO_2 concentration), occupancy data (if a room is occupied or not), electricity usage information for each device (provided by the smart plugs or by smart appliances), overall electricity usage (provided by the smart meter). By default, the sensors will be configured to send telemetry data every 15 minutes, but the interval can be adjusted.

The entry point for these data is the IoT Hub, next they are processed by Stream Analytics and sent to the Azure Storage service to store them in blobs or to the Power BI service to display them.

The telemetry data flow might be sent to blobs or to visualization dashboard in different forms of aggregation: unprocessed, meaning that raw data will be sent, just as they were received from sensors and devices; statistics, calculating different statistical values over a time period (minimum, maximum, total, average); filtered, meaning that only values that meet specific criteria are sent (for example, values above or below a threshold, that generate notifications).

- Device metadata. These are received when a device is added to the system or is replaced or its firmware is updated. The metadata provide information about the main characteristics of the device and are stored in the Cosmos DB database.

- Device status data. They provide information about the sensors' status. For example, if a sensor does not send any data over a period of time (e.g. an hour), it can be assumed that it has connectivity problems, or it might be disabled; or if it sends abnormal values, the sensor might be broken or malfunctional. This should immediately trigger notifications and alerts.

The solution will include automatic feedback loops. For instance, if a sensor records telemetry data outside a certain normal operating range, this will automatically trigger an event, leading to a status change of that sensor. A notification will be pushed into the Event Hub and the event processor will decide the appropriate response action (e.g. restart the sensor, reset to factory settings, update the firmware). The solution will then send a command to that sensor to take corrective action and afterwards check the telemetry values once again to see if the action had fixed the problem.

The data come from the device through the IoT Hub and are sent to be stored in status reports blobs or directed to the Event Hub, in case a status change had triggered an event.

- Threshold values used as reference values when generating notifications and alerts. They might be fixed or can be stored in a different table, so that the user is able to change their values, depending on his preferences. There can be different thresholds for the same data flow, depending on the notifications, alerts, and actions that the user wants to be triggered.

For example, the owner can set different temperature ranges, depending on the comfort level, preferences, and daily program of the household occupants. Thus, the system might have some thresholds for comfort temperature level (e.g. between 20 and 23 degrees Celsius), other reference values for economic electricity consumption (18 to 25 degrees), and others for minimal settings (if a room or the household is not occupied for a long period of time, the minimal temperature settings could be between 10 and 35 degrees Celsius).

Some other examples of notifications might be: if the total consumption at some point exceeds the monthly average by more than 20%, the owner should be notified; if there is no recorded electricity usage for more than one hour, this might signal an interruption of the electricity supply.

Generating notifications and alerts will depend on filtering those values that are outside the thresholds limits. The notifications will be pushed into the Event Hub and will also be stored into the designated notification blob and into the status reports blob.

The telemetry data are used for real-time analyzes, necessary for making quick decisions, or for periodic analyzes running at regular intervals, to check the behavior of a particular device (e.g., HVAC system), or for gathering historical data (over time) for more in-depth analyzes that use machine learning algorithms to determine consumption patterns and make estimations and predictions.

In order to precisely estimate the daily or monthly energy consumption, it is necessary to collect historical data over long periods of time (months / years), so that certain operation patterns can be established for each appliance [3], but also to assess the behavior of the household occupants. For monitoring the energy consumption of individual appliances, smart plugs and outlets are used, but also the data provided by the smart devices directly. For the overall household consumption, the information will be provided by the smart meter. The smart meter plays an important role, since knowing at every moment the up-to-date electricity consumption can lead to immediate decisions (for example, if the current consumption level is much bigger than the estimated one). In addition, permanent monitoring of household energy usage can persuade the occupants to be more responsible.

The data provided by the smart meter will be the basis of performing calculations and prediction analyses. The system will calculate the up-to-date value of the energy bill, but can also use our prediction algorithms to estimate the electricity consumption for the current month.

Starting from these estimations, optimization algorithms can be applied to reduce the energy usage. For more precise optimizations, the occupants' behavior needs to be assessed, and patterns should be established by analyzing historical data.

The IoT solution will include a decision support system that, according to some rules, will provide tips or recommendations to the user, such as: "*by switching to the economical HVAC running scheme, the electricity bill is estimated to be reduced by ... Euro*"; "*if choosing the minimal HVAC regime when the household is unoccupied, will reduce the bill even more by ... Euro*"; "*by lowering the temperature to 21 degrees, you will save ... kW*"; "*if you reschedule the washing machine / dryer / dishwasher to run outside the peak hours (when the energy is cheaper), you might save ... Euro*"; "*you can program the boiler to work during the night (or early morning) and reduce the energy costs by ... Euro*"; "*if a room is unoccupied for a long period of time (more than one hour), set the HVAC system to run on minimal functioning regime*".

This decision and prediction module might use Machine Learning functions, in order to take advantage of the intelligent solutions provided by this service, or use our custom-tailored forecasting solutions, or call user-defined JavaScript functions, to perform complex calculations (as part of a query).

7. REPORTING AND VIEWING COMPONENT

The presentation component will allow the users to manage the IoT solution and, through it, interact with the connected devices. The users will access the interface through web or mobile applications that use the functionalities provided by the Power BI service. Power BI is a cloud service especially designed for presenting and viewing data; its flexibility allows the rapid building of interactive reporting boards for the IoT Suite data [9].

The system interface allows the complete management of the implemented solution. For instance, telemetry data can be viewed (as reports or charts that display both real-time and historical values), generated reports can be saved or exported, devices can be managed, rules and actions can be configured. All actions can be performed remotely from the solution dashboard, there is no need to directly interact with the devices.

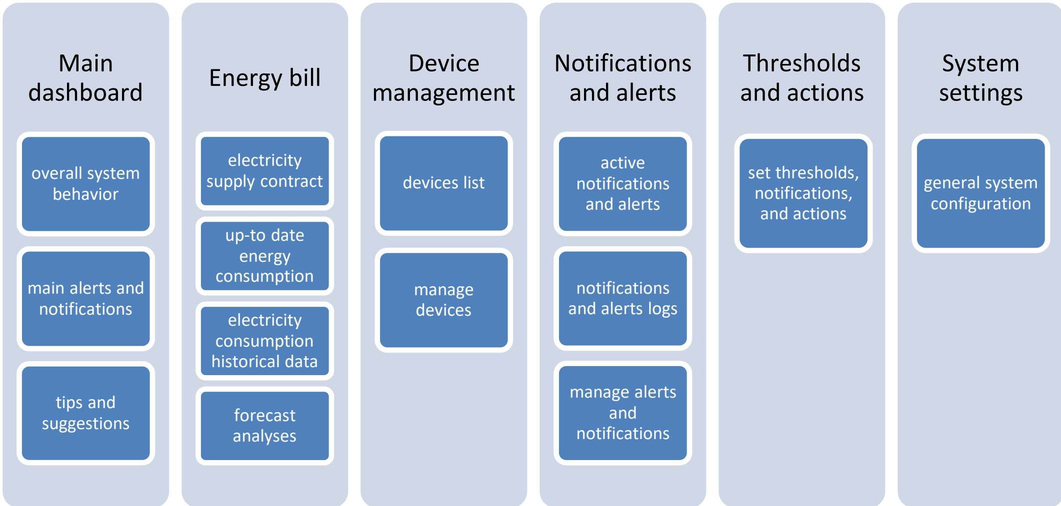

Figure 2. The IoT solution dashboard

The dashboard can present real-time and historical information based on the telemetry data stored in blobs; it can show the results of the forecast analyses and offer tips and suggestions for reducing electricity consumption; it can display information regarding the device status or configuration, existing notifications and alerts; it will allow the user to perform various actions, modify alert thresholds, send commands to devices, schedule jobs, etc.

The components of the system interface are detailed in Table 1.

Table 1. The components of the solution dashboard

Sections	Subsections	Provided functionalities
Main dashboard	overall system behavior	display graphical representations of instant telemetry values read by the sensors; display charts of historical energy consumption data over a time period (last hour / day / month); options for generating, saving and exporting reports;
	main alerts and notification (on the overall system)	view general alerts and notifications, such as: “interruption of the electricity supply” (alert); “energy consumption is foreseen to exceed the monthly average” (notification);
	tips and suggestions	display suggestions for solving the problems that caused the alerts and notifications; in case of no active notifications, display random suggestions; possibility to view more optimization tips and suggestions;

Energy bill	electricity supply contract	view / upload / manage the electricity supply contract and current price plans used;
	up-to date energy consumption	display up-to-date information, retrieved from the smart meter, regarding the total consumption; graphical representation of historical values recorded by the smart meter over a specific time period (last week / month / for the current bill); display simple statistical information, such as: minimum / maximum daily consumptions and the dates they were recorded, average daily consumption;
	historical data of the household energy usage	list the electricity bills from previous months; display and chart the recorded monthly electricity consumption values over a specific period (e.g. last year); display statistical information for historical monthly consumption values (average / minimum / maximum); for a selected bill, provide comparative values if the owner had chosen another price plan or contracted another supplier;
	forecast analyses	estimate the value of the current bill; estimate current bill if choosing a different price plan or electricity supplier; display consumption predictions over a time frame from the near or far future;
Device management	list of devices connected to the system	display the list of sensors and appliances included in the system; options to add, remove, replace devices; options to sort, filter and group devices according to their type and status;
	manage individual devices	view metadata information; view status information; view notification history for the device; update firmware / hardware; change device settings; display telemetry values recorder by the device; set threshold values; schedule a job for that device (e.g. set the AC unit to start at 2 P.M.; set the boiler to start at 5 A.M.)
Notifications and alerts	active notifications and alerts	display all active notifications and alerts; options to sort, group and filter notifications according to: priority / alert level, timestamp, device involved;
	notifications and alerts logs	display past notifications and alerts sorted descending by their timestamps; filter the devices generating most alerts;
	manage individual alerts and notifications	display information about the selected notification / alert; option to remove or ignore it; suggest possible corrective actions such as: reboot the system; restart a device, update its firmware, disable it; and let the user choose the action;

Thresholds and actions	set thresholds, notifications, and actions	set the threshold values for each type of sensors or for an individual sensor, for different functioning regimes; set the alert level for each threshold; set the actions to be performed when the threshold value is exceeded (e.g. automatically start the AC unit when temperature is above the comfort value, or just notify the user and let him decide if the room is unoccupied); specify if the action will be triggered automatically or manually;
System settings	general configuration of the system	display general information about the system, such as: number and types of sensors and appliances; last reboot; total functioning hours; let the user perform specific actions on the system: check its status, reboot the system, update the software; set different functioning regimes, for example: comfort, economical, minimal; switch to a different comfort plan; set the daily program of the household occupancy and users' preferences; view / change settings of weather forecast provider; display the weather forecast.

8. CONCLUSIONS

The IoT solution proposed here combines the functionalities provided by the Azure IoT Suite services, in terms of device connectivity, data collection, data analysis and processing, machine learning algorithms, presentation and design, etc. and especially the possibility to integrate custom tailored developed modules, in the form of Python packages that can tackle and solve complex problems that could not have been solved using only the existing tools of the Azure IoT Suite.

The system offers the user relevant real-time and historical information than can assist him in the consumption-related decision making, and also supports automating operations that will offer benefits for both increasing the user's comfort and reducing electricity usage. The Remote Monitoring preconfigured solution could be used as a starting point in developing the system. The operation of configuring the present IoT solution will imply connecting devices and sensors to the cloud, collecting, storing and analyzing the data they record, making prediction analyses using the forecast method that we developed, and suggesting solutions and taking decisions for optimizing electricity consumption based on the estimations provided by the system. The solution dashboard, presented as web page or mobile application, will implement capabilities for the complete management of the system.

Viewed from the business perspective, the present IoT solution might be sold as an additional service by the energy supplier or by third party companies (IT companies, consultancy providers). Depending on the user's preferences (and budget) the system could be fully automated (making decisions, taking actions for optimizing electricity consumption) or not (only sending notifications, alerts, predictions, and suggestions).

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REFERENCES

[1] Popa C., Căruțașu G., Cotet C., Căruțașu N., Dobrescu, T.; *Smart City Platform Development for an Automated Waste Collection System*. Sustainability 2017, 9, 2064, doi:10.3390/su9112064.

[2] Căruțașu G., Coculescu C., Stănică, J.L., Pîrjan A.; *An analysis of the main characteristics and implementation requirements of the advanced metering infrastructure systems in Romania*, Database Systems Journal vol. VII, issue 3 / 2016, pp. 34-45, ISSN 2069 – 3230;

[3] Moreno M.V., Úbeda B., Skarmeta A.F., Zamora M.A.; *How can we tackle energy efficiency in IoT based smart buildings?*, Sensors (Basel). 2014, 14, 9582–614, doi:10.3390/s140609582, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4118407/.

[4] Vermesan O., Friess P.; *Internet of Things Applications - From Research and Innovation to Market Deployment*, Aalborg: River Publishers, 2014.

[5] Microsoft. *Azure IoT Suite*. Available online: https://azure.microsoft.com/en-us/suites/iot-suite/ (accessed on 13.03.2018).

[6] Microsoft. *Azure and the Internet of Things*. Available online: https://docs.microsoft.com/en-us/azure/iot-suite/iot-suite-what-is-azure-iot (accessed on 13.03.2018).

[7] Microsoft. *Overview of the Azure IoT Hub service*. Available online: https://docs.microsoft.com/en-us/azure/iot-hub/iot-hub-what-is-iot-hub (accessed on 13.03.2018).

[8] Microsoft. *What is Stream Analytics?* Available online: https://docs.microsoft.com/en-us/azure/stream-analytics/stream-analytics-introduction (accessed on 13 March 2018).

[9] Microsoft. *Power BI Documentation*. Available online: https://docs.microsoft.com/en-us/power-bi/#pivot=home&panel=home-all (accessed on 13.03.2018).

[10] Maik van der Gaag, *Azure IOT*, presentation, https://www.slideshare.net/maikvandergaag/azure-iot-64759215?qid=662460be-5ca9-4eda-94e5-31133d406201&v=&b=&from_search=1 (accessed on 01.05.2018)