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Abstract:
This document provides the software release of the final version of the integrated ENTROPY Platform, along with short documentation regarding the development, integration and usage of the ENTROPY Platform (including end-users’ manual and engineers’ installation and customization guidelines).

Keywords:
ENTROPY Platform, Sensor Data Management, Semantic Mapping, Data Mining and Analysis, Personalised Recommendations

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Revision History

The following table describes the main changes done in the document since created.

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Executive Summary

In the current document, short description of the integrated version of the ENTROPY platform, as well as the final version of the developed serious game and personalized application is provided. Focus is mainly given on the main technologies used for the design and development of the platform and mobile applications, guidelines towards software developers and IT administrators aiming to deploy the ENTROPY platform over their infrastructure, as well as guidelines for the usage of the platform by campaign managers and end users. The main objective is to provide an overview of the overall functionalities provided by the ENTROPY platform, supporting potential adopters to easily deploy the overall platform, manage the available infrastructure and realize campaigns with the active involvement of end users. Furthermore, the main innovations introduced by ENTROPY are detailed along with the potential for adoption and extension of the provided platform in the future. The material presented in this document along with the availability of the software in the denoted GitHub repository can constitute the basis for the replication of the ENTROPY solution in numerous deployments targeting at exploiting the provided IT ecosystem towards behavioral change of consumers and adoption of energy efficient lifestyles.

Disclaimer

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1. **INTRODUCTION**

In this document, short description of the integrated ENTROPY platform is provided, focusing on the developed software, the software technologies selected and used and the deployment and usage guidelines. The document accompanies the delivery of the overall software of the delivery of the first integrated version of the platform that is made available through https://github.com/ubitech/entropy. Furthermore, description of the final version of the developed serious game and personalized application is provided, focusing on the main technologies used and the main functionalities provided.

It should be noted that in ENTROPY, a set of novel ICT technologies are used, adopted and integrated in the platform covering software components and kits from the Internet of Things (IoT), information fusion, semantic web, rule-based recommendations, big data mining, and analysis mechanisms areas. All the aforementioned technologies are supported through an integrated IT ecosystem that comprises the basis for the consumption of existing services, as well as the design and development of further energy management and awareness services, personalized mobile applications, and serious games. Personalized mobile applications and serious games development is realised taking advantage of the information and analysis results provided by the platform through open APIs.

The structure of the document is as follows: in section 2, the main technologies used for software development of the various ENTROPY components are detailed, including the description of the software organization in terms of modules and functionalities, basic deployment guidelines as well as usage guidelines for the ENTROPY platform by end users and campaign managers. In sections 3 and 4, the main technologies used for software development of the Augmented Reality (AR) Treasure Hunt Serious Game and the Energy Awareness Personalised Application are detailed, along with the main software modules developed and the interaction with the platform and software deployment and usage guidelines. Section 5 provides short description of the main innovation characteristics of the ENTROPY platform, focusing on the set of services provided by the integrated platform through open APIs, while section 6 provides short conclusions for the document.
2. **INTEGRATED ENTROPY PLATFORM**

A high-level view of the ENTROPY energy-aware IT ecosystem architectural approach is provided in Figure 1. As depicted, a layered architecture is followed based on the ENTROPY Conceptual Architecture described at D1.3 [1] with discrete layers for IoT management and data aggregation, data representation and fusion, smart energy management services and end user applications. The IoT management and data aggregation layer is responsible for IoT nodes registration, management and data aggregation and cleaning functionalities at the edge part of the infrastructure. The data representation and fusion layer is responsible for representing the collected data based on a set of defined semantic models as well as supporting a set of data fusion mechanisms over active data streams. The smart energy management services layer is responsible for providing advanced analytics and recommendations to end users, as well as incorporating learning techniques for continuously exploiting the produced output by each service. The end user applications layer is responsible for the design of personalized mobile applications and web-based serious games able to take advantage of the set of services provided by the lower layers.

![Figure 1. Energy-aware IT ecosystem architectural approach.](image-url)
Following, short reference regarding the main technologies used for implementing the various ENTROPY components per layer is provided. All selected technologies are open source with large communities of developers that constantly supports them.

### 2.1 Main Technologies Used

At this section, short reference to the main software technologies adopted for the development of the ENTROPY platform is provided.

At the IoT management and data aggregation layer, a set of cloud-based open enablers are used, provided by the European platform for Future Internet FIWARE. These enablers are orchestrated together by means of lightweight RESTful Application Programming Interfaces (APIs) according to the Open Mobile Alliance Next Generation Service Interface (NGSI) 9-10 standard [2].

Regarding the usage of the FIWARE enablers in the ENTROPY ecosystem:

- The FIWARE enabler called IoT Agent is used for the registration of the sensor nodes and the collection of sensor data in real-time [3]. The IoT Agent acts as a gateway for hardware devices. It supports a set of communication protocols (e.g., Constrained Application Protocol (COAP), MQ Telemetry Transport (MQTT), Lightweight Machine-to-Machine (LWM2M)) for establishing connectivity with the sensor nodes and retrieving data in real-time.
- Orion Context Broker (OCB) [4] is used to store and manage in a structured and homogeneous way the data of the infrastructure sensor nodes.
- A sensor data cleaning process takes place for improving the overall data quality through the usage of the FIWARE Complex Event Processing (CEP) enabler called PROTON [5].
- COMET FIWARE enabler is used for supporting access to historic time series data [6]. It incorporates several built-in simple aggregation functions over the historic sensor data (e.g., provide sum, minimum, or maximum values). Access to such data is considered very helpful for realizing comparisons, providing input to data mining and analysis processes as well as describing rules that can lead to personalized recommendations.

At the Data Representation and Fusion layer, the main technology used is MongoDB. MongoDB is a free and open-source cross-platform document-oriented database program. Classified as a NoSQL database program, MongoDB uses JSON-like documents with schemas. Such a choice is made mainly by considering the supported load balancing and sharding characteristics. In order to support the storage of data without losing their expressivity in terms of their mapping to the semantic models and in parallel ensure high-performance characteristics during data management and reasoning processes, data is stored in JSON-LD format that stands for JavaScript Object Notation for Linked Data. JSON-LD is a method of encoding linked data using JSON. Using MongoDB and JSON-LD together is considered optimal in cases that combination of efficient representation schemes along with efficient data retrieval mechanisms has to be realized.

At the Smart Energy management services layer, the main services provided by the ENTROPY platform are developed. To do so, it has been made use of many state-of-the-art technologies that are listed as follows:

- Java8 has been used as programming language for coding the ENTROPY. Java is a general-purpose computer-programming language that is concurrent, class-based, object-oriented, and specifically designed to have as few implementation dependencies as possible [7]. ENTROPY platform makes use of the Spring Framework. Spring Framework is an
application framework and inversion of control container for the Java platform. The framework's core features are basically extensions for building web applications on top of the Java EE (Enterprise Edition) platform.

- ENTROPY components are built and deployed together thanks to Apache Maven build automation tool. Maven addresses two aspects of building software: first, it describes how software is built and second, it describes its dependencies. Maven dynamically downloads Java libraries and Maven plugins from one or more repositories such as the Maven 2 Central Repository and stores them in a local cache. The Maven project is hosted by the Apache Software Foundation [8].

- Interoperability between the ENTROPY platform and external apps such as the serious game, personal mobile app and FIWARE enablers is done by using the power of REST APIs. REpresentational State Transfer (REST), or RESTful, web services provide interoperability between computer systems on the Internet. REST-compliant web services allow the requesting systems to access and manipulate textual representations of web resources by using a uniform and predefined set of stateless operations.

- Regarding the ENTROPY recommendation engine, it has been developed making use of the Drools technology. Drools is a Business Logic integration Platform (BLiP) written in Java and is an open source project [9]. Drools give the mechanics to use a powerful rule engine that allows to define “What to Do” and not “How to do it.” Unlike codes, Rules are written in less complex language that means that entropy campaign managers can easily create and verify set of rules.

- Asynchronous communication between ENTROPY modules is done via the use of a very well-known and open source pub/sub framework, namely Apache ActiveMQ. Apache ActiveMQ is an open source message broker written in Java together with a full Java Message Service (JMS) client [10].

- The analytics module of ENTROPY combines two very promising open source technologies. These are the R language and openCPU server. The second one provides a reliable and interoperable HTTP API for data analysis based on R [11]. On the other hand, R language is a programming language and free software environment for statistical computing and graphics that is supported by the R Foundation for Statistical Computing. The R language is widely used among statisticians and data miners for developing statistical software and data analysis [12].

Last but not least, at the end-user application layer, there are developed two mobile applications (a serious game and a personalised application). The technologies that are used to develop each one of them are Android Development Kit and Unity:

- Unity is a cross-platform game engine developed by Unity Technologies, which is primarily used to develop both three-dimensional and two-dimensional video games and simulations for computers, consoles, and mobile devices [13].

- Android is a mobile operating system developed by Google, based on a modified version of the Linux kernel and other open source software and designed primarily for touchscreen mobile devices such as smartphones and tablets [14]. Android SDK and Android Studio are being used for the design and development of Android applications.

Detailed description of the developed applications is provided in section 3 and 4 of this document.
2.2 Main software modules and integrated software

ENTROPY ecosystem consists of a set of components. Its modularized nature per feature makes easier the maintenance and readiness of code. As it can be seen at the ENTROPY GitHub repository in Figure 2, the code is split at seven different modules. Following, there are presented the main functionalities of each of the components.

**Figure 2.** Entropy GitHub repository.

### API Component

At this component, there are defined all the possible interfaces that are used between all other components. Having all interfaces defined in a homogeneous way, it helps a lot for maintaining and extending the project code.

### APP Component

This component consists of the ENTROPY platform as a GUI (graphical user interface). It is one of the three executables and defines all available navigations links, javascript libraries, end-user permissions etc.

### Repository Component

All ENTROPY classes’ definition can be found at the Repository Component. Thanks to the Java Persistence API (JPA) application programming interface, the Repository component implements the API interfaces so as to make queries against entities stored in the mongoDB in an optimal way.

### Monitoring Component

Monitoring Component deals with all the communication with FIWARE enablers in a scheduled way. Cron Jobs are defined through the platform by the ENTROPY administrators and campaign managers and are executed as pool of threads within the monitoring component. Monitoring Component is an executable that can be hosted with the app component or can be placed at a different virtual machine/container.
**Recommendation-engine Component:** Recommendation-engine is the third executable of the ENTROPY ecosystem. It contains all the functionality related with the enforcement of the recommendation rules created by the campaign managers.

**Rest-API Component:** Rest-API Component contains all the rest API’s that make possible the interoperability of the ENTROPY platform with third party applications such as the serious game and the personalized apps. Exposed API’s are placed at the ENTROPY GitHub wiki, where is clearly explained how third-party apps can retrieve and send information at the platform. Following, it can be seen the list of supported APIs in Figure 3 as well as a definition example of a sample rest call in Figure 4.

**Exposed API’s**

- Login
- Get SensorDataStream values
- Execute a query
- Retrieve Historic Recommendations
- Get end user actions
- Initialize and Update User Profile per App
- Get Top users per App
- Get user profile per App
- Return Feedback from Recommendation
- Send a new Action
- Get Registered Areas
- Get building sub-areas
- Get SensorDataStreams per building for a list of attributes
- Get consumption profile of a building
- Get consumption profile of all buildings
- Get latest measurement from main streams of an area building

Figure 3. Set of Exposed API’s at Entropy GitHub wiki.
Util Component: Util component contains a set of useful functions that are shared among the components such as security functions, serialization and deserialization functions etc.

2.3 Software deployment guidelines

The software deployment guidelines are included at the README.md file that is also part of the ENTROPY repository as can be seen at Figure 2. README.md file includes a set of prerequisites the execution environment should have, before deploying the three ENTROPY executables. These include previous installation of:

- JDK 1.8.0_latest
- Maven 3.x
- R 3.4.x
- Mongo 3.4.x
- Apache activemq the latest
- OpenCPU the latest

Figure 4. Example of Rest API description.
README.md file also contains the specific commands in order to build the and run the executable components. For each of the components the developer has to check out the code, make some extra configurations at the application.properties file (this is optional), build the code and launch the component. In Figure 5 can be seen the commands as presented at the Git-Hub repository regarding the launching of the app, monitoring and recommendation-engine components.

**Run the Application**

```
$ git clone git@github.com:ubitech/entropy.git
$ cd entropy
$ mvn clean install
$ cd app
$ mvn spring-boot:run

Note: The configuration file for the app can be found https://github.com/ubitech/entropy/blob/master/app/s
```

**Run the Monitoring Engine**

```
$ cd entropy
$ mvn clean install
$ cd monitoring
$ mvn spring-boot:run

Note: The configuration file for the app can be found https://github.com/ubitech/entropy/blob/master/monito
```

**Run the Recommendation Engine**

```
$ cd entropy
$ mvn clean install
$ cd recommendation-engine
$ mvn spring-boot:run

Note: The configuration file for the app can be found https://github.com/ubitech/entropy/blob/master/recc
```

**Figure 5. Deployment guidelines at a development environment.**

All the aforementioned guidelines are recommended for a development environment. In case the ENTROPY platform is deployed at a production environment, some extra configuration should be done. For that purpose, there has been created a set of scripts available at the config folder of the ENTROPY GitHub repository. Following, in Figure 6, these scripts are shortly presented. The objective is to facilitate the easy deployment of the ENTROPY platform at a cloud environment where the ENTROPY app, monitoring, recommendation and analytic microservices maybe reside or not at the same virtual machine.
Figure 6. Deployment scripts at a production environment.

**prepareEntropyVM.sh**
Prepare EntropyVM installs all the necessary software packages at a clean linux machine, previous to ENTROPY platform deployment. This includes:

- installation of last maven packages,
- apache2,
- openjdk-8-jdk,
- activemq (version 5.15.6)
- fetch entropy code from GitHub repository
- installation of mongo and enablement of the necessary authentication mechanisms
- installation of logrotate for easy administration of ENTROPY log files (automatic rotation, compression & removal of log files)

**prepareEntropyAnalyticServer.sh**
In case the analytic microservice is enabled, some extra packages should be installed. The current script can be executed at the same virtual machine as before or a new one. The EntropyAnalyticServer script installs all necessary software packages that are related with the smooth operation of the analytics execution services inside the ENTROPY platform. ENTROPY platform is designed to consume analytic services that come from more than one analytic server and can consume all kind of analytic services that respect the OpenCPU API protocol. However, the ENTROPY platform can also operate independently of any analytic service. The current script includes:

- installation of R language packages,
- OpenCPU server,
- Rstudio,
- Fetch & install all EntropyRPackages available at [https://github.com/ubitech/EntropyRPackages](https://github.com/ubitech/EntropyRPackages)

**initEntropyPlatform.sh**
As it’s name indicates, initEntropyPlatform script instantiates the ENTROPY platform. To do so following steps are followed:

- Instantiation of mongo,
- Activemq
• Build the code from source of ENTROPY platform
• Start some or all of the ENTROPY microservices (app, monitoring, recommendation)

initEntropyPlatform script also demands two parameters
• $mongo_bind_ip refers to the mongo ip the mongo server should be remotely accessible
• $Entropy_active_profile refers to the application properties with all environmental parameters that should be activated at the current deployment. Application properties files can be found at /app/src/main/resources of app microservice repository. It is very easy to generate a new one in case is needed.

For example, the following command instantiates a mongo server accessible at ip 192.168.100.17 and enables all the environmental and application specific variables declared at application-test.properties file.

```bash
./entropy/config/initEntropyPlatform.sh 192.168.100.17 test
```

**stopEntropyPlatform.sh**

For an easy un-deployment of the ENTROPY platform, it can be used the stopEntropyPlatform script where all active microservices are stopped as well as the mongo database server.

### 2.4 ENTROPY Platform Handbook

The ENTROPY platform Handbook aims to reveal in a structured and detailed way all the functionalities supported by the ENTROPY platform. It is a valuable and necessary tutorial used by administrators and campaign managers who orchestrate all the behavioural focused energy related campaigns. The handbook regards a live online documentation that is available through the following link: [https://entropy-platform-handbook.readthedocs.io/en/latest/](https://entropy-platform-handbook.readthedocs.io/en/latest/)
3. **AUGMENTED REALITY (AR) TREASURE HUNT SERIOUS GAME**

3.1 Main Technologies Used

Augmented Reality Treasure Hunt serious game was developed using Unity game engine. It is a flexible and high-performance end-to-end development platform used to create rich interactive 3D and 2D experiences, providing support for the development of both Augmented and Virtual Reality applications. Unity's powerful graphics engine and full-featured editor serve as the foundation to develop beautiful games or apps and easily bring them to multiple platforms: mobile devices, home entertainment systems, personal computers, and embedded systems.

In summary, AR Treasure Hunt serious game was developed using following technologies:

- Unity game engine
- C# programming language,
- Vuforia sdk for AR functionality it is used
- OneSignal sdk for Push notifications (to make Actions available when the app is off)

3.2 Main software modules and interaction with the Platform

AR Treasure Hunt supports the following main functionalities:

- User Login (signup at Entropy web portal)
- Voucher system – QR vouchers mechanism to award prizes to the players
- AR Clues - image markers that can be scanned with device camera to trigger appearance of additional AR content on the mobile phone
- Q&A multiple questions and single question
- Hints
- Point based awards mechanism
- Scoreboard – shows points gained by the user
- Recommendations (i.e. Actions) – received in a real time through push notifications
- Connection to Entropy Broker to get recommendations
- Badges – assigned according to the award mechanism for completed Actions based on real time recommendations
- AR Data Visualisation – real time sensor data displayed per location
The following Application Programming Interfaces (APIs) have been utilized to access and send data to the Entropy platform:

<table>
<thead>
<tr>
<th>Functionality</th>
<th>Scope</th>
<th>Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Login as an Entropy end user</td>
<td>The sign in of an existing user to the ENTROPY platform. If the user exists then the ENTROPY Platform returns an authentication token to the client (web app, android, personal app or serious game).</td>
<td>http://server_IP_address/api/v1/auth/login</td>
</tr>
<tr>
<td>2 Get Observation Values from a Sensor</td>
<td>This functionality is used for getting observation values from a sensor.</td>
<td>http://server_IP_address/api/v1/observations/filter</td>
</tr>
<tr>
<td>3 Get All Recommendations per end user</td>
<td>Retrieve all recommendations per end user.</td>
<td>http://server_IP_address/api/v1/recommendation/collection</td>
</tr>
<tr>
<td>4 Get End User Actions</td>
<td>Analyze and manipulate further the submitted actions metadata (related or not to a specific action) in a period of time.</td>
<td>http://server_IP_address/api/v1/recommendation/customAttributes</td>
</tr>
<tr>
<td>5 Initialize User Profile per Application</td>
<td>Initializing &amp; updating a user profile per application. if the app_name does not exist then is initialized, otherwise is updated.</td>
<td>http://server_IP_address/api/v1/app/update</td>
</tr>
<tr>
<td>6 Get personal data of gamer</td>
<td>Getting the basic personal data of the gamer.</td>
<td>http://server_IP_address/api/v1/app/userprofile</td>
</tr>
<tr>
<td>7 Return Positive or Negative Feedback from a Recommendation</td>
<td>Getting back the positive or negative response of a user to a recommendation.</td>
<td>http://server_IP_address/api/v1/recommendation/feedback</td>
</tr>
<tr>
<td>8 Send A new Action</td>
<td>To inform ENTROPY platform that a new action has been realized, and it should be taken into account by the recommendation engine as a new context change.</td>
<td>http://server_IP_address/api/v1/recommendation/action</td>
</tr>
<tr>
<td>9 Get SensorDataStreams per building for a list of attributes</td>
<td>Retrieving all sensor data streams that are located into a specific building space and monitor a list of attributes.</td>
<td>http://server_IP_address/api/v1/sensor/building/{building_name}/getstreams</td>
</tr>
</tbody>
</table>

### 3.3 Software deployment guidelines

In order to run the AR Treasure Hunt game, the following actions are required per stakeholder:

**Pilot manager:**
- Prints the AR markers
- Places the AR markers in different rooms
- Prints QR Code and the location where the validation and distribution of prizes will be organized

**Users/Players:**
- Android users download application from owncloud and install it
- iOS users install test flight application from iTunes and after that user will receive notification in test flight application to install TH game.
- Start the TH Entropy application
- Login and
- ENJOY playing it!
3.4 Main Usage Scenario/User Manual

The Entropy TH game consists of two types of questions: AR and Q&A clue type questions. **AR Clue Type** of question consists of a text clue that should lead the player to scan an image marker, as you can see in Figure 7, using the phone's camera that opens automatically when the 'scan' button is pressed. The player then scans the marker, and the Augmented Reality (AR) content is shown. That AR content is then the clue to the next question.

![AR Clue – image marker](image.png)

**Figure 7. AR Clue – image marker**

**Multiple Choice Question (MCQ)**

In Multiple Choice Question (MCQ) question, the player must choose only one correct of the four possible answers. Figure 8 shows one of those MCQs. If the chosen answer is wrong the points will be deducted from the max score for this question. In **Text Type Question**, the player has to type the correct answer into the text box, as you can see also in Figure 8.
## Multiple Choice Questions

How is light bulb brightness measured?

- Watts
- Lumens
- Joules
- Footcandles

Text Type Question

Please guess the temperature (in Celsius) in the Chemistry room at Murcia University?

- Answer Here

Congratulations

Treasure Hunt still in progress

00.05.03 TO END

Congratulations Marcelo!

You are currently in 1st position.
Please check scoreboard at the end of TH to discover if you won some prizes.

Score: 253

Play Again

---

**Figure 8. Multiple Answer and Text Questions**
Hints
If you get stuck on any of the questions, you can simply tap the ‘hints’ tab, and you will have three available hints, to help you with solving the question, but each hint used will reduce the number of points awarded for that question by 10%. Figure 9 shows the disclosure process of some hints. In addition, if you use the ‘skip’ button you will be transferred to the next question, but will score no points for the previous one.

<table>
<thead>
<tr>
<th>HINTS</th>
<th>HINTS</th>
<th>HINTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use hints to solve the clue, but beware, the points will be lost</td>
<td>Use hints to solve the clue, but beware, the points will be lost</td>
<td>Use next hint to solve the clue, but more points will be lost</td>
</tr>
</tbody>
</table>

Scoreboard
When the game has ended you will be taken to the scoreboard screen (Figure 10), where you can see how your score compares to the other players of the TH game.

Figure 9. Hints
Figure 10. Personal Score and Scoreboard
Sensor Data Visualization

When you see the “eye” blinking you can visualize the sensor data in that room, by tapping the “eye” button as shown in Figure 11.

![Figure 11. Real time sensor data visualisation](image)

Recommendations

When the recommendation notification appears, tap the “menu” button, then “My Actions” and “Active” after that. Then, choose from the available active actions. Once the action is chosen, read the recommendation and act on it. When you are done, tap the “Done” button to send us the info that you have successfully completed the recommendation. This steps are shown in Figure 12.

<table>
<thead>
<tr>
<th>My Actions Active, Done and Achievements</th>
<th>Active Actions Based on Recommendations</th>
<th>Active Actions Achievements – badges won</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="My Actions" /></td>
<td><img src="image" alt="Active Actions" /></td>
<td><img src="image" alt="Achievements" /></td>
</tr>
</tbody>
</table>

...
Figure 12. Recommendations to do energy saving Actions
You can always see the list of your accomplished recommendations under the “Done” tab. For every accomplished recommendation you will receive an achievement badge. After receiving 5 achievement badges, you will receive the Ultimate Badge!

My Prizes
You can always see the list of all available prizes that can be won by playing the TH game. Under the “Valid” tab you can see the list of prizes that are available for validation. By tapping on one of the valid prizes, you will be prompted to proceed with the validation of the prize.

<table>
<thead>
<tr>
<th>Available Prizes</th>
<th>My Prizes</th>
<th>My Prizes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prizes to be won in the game</td>
<td>Prizes won in the TH game</td>
<td>can be validated through the AR TH app or sent to a friend</td>
</tr>
</tbody>
</table>

Figure 13. Prizes that can be won

Voucher Validation
To validate your voucher simply tap on the QR code. Camera will turn on. In order for your voucher to be successfully validated, scan the “Validation QR Code” at place where the prize is located.

Figure 14. Voucher validation
4. ENERGY AWARENESS PERSONALISED APPLICATION

4.1 Main Technologies Used

Energy Awareness Personalized Application is a native Android Application developed in Java 8. Java protects developers from many of the problems inherent in native code, like memory leaks, bad pointer usage, etc. The two main external libraries used for this application are: Retrofit Android and MPAndroidChart. Retrofit is a REST Client for Java and Android and handles all the REST communication with the platform. MPAndroidChart is a powerful Android chart view / graph library responsible for the creation of all the graphs of the application.

4.2 Main software modules and interaction with the Platform

This application is fully integrated with the Rest APIs of Entropy Platform. All the content of the application is being retrieved from the services of the platform, the generated data produced by the usage of this App are being pushed back transparently, to the platform.

The following APIs are being used by this Application:

- [https://github.com/ubitech/entropy/wiki/Method-2---Login-as-an-Entropy-end-user](https://github.com/ubitech/entropy/wiki/Method-2---Login-as-an-Entropy-end-user) - Login functionality
- [https://github.com/ubitech/entropy/wiki/Method-8---Get-Observation-Values-from-a-Sensor](https://github.com/ubitech/entropy/wiki/Method-8---Get-Observation-Values-from-a-Sensor) - Get observation values for a specific data stream
- [https://github.com/ubitech/entropy/wiki/Get-End-User-Actions](https://github.com/ubitech/entropy/wiki/Get-End-User-Actions) - Return end user actions per app for specific period of time
- [https://github.com/ubitech/entropy/wiki/Initialize-and-Update-User-Profile-per-Application](https://github.com/ubitech/entropy/wiki/Initialize-and-Update-User-Profile-per-Application) - Initialize and update a user profile for a specific application
- [https://github.com/ubitech/entropy/wiki/Get-User-Responsiveness-To-Generated-Recommendation-for-Active-Campaign](https://github.com/ubitech/entropy/wiki/Get-User-Responsiveness-To-Generated-Recommendation-for-Active-Campaign) - provide basic statistics with regards to the responsiveness of an end user to recommendations
- [https://github.com/ubitech/entropy/wiki/Method-11----Return-Positive-or-Negative-Feedback-after-receiving-a-Recommendation](https://github.com/ubitech/entropy/wiki/Method-11----Return-Positive-or-Negative-Feedback-after-receiving-a-Recommendation) - retrieve positive or negative feedback by an end user for a recommendation
- [https://github.com/ubitech/entropy/wiki/Method-7---Get-All-Building-Space-Areas](https://github.com/ubitech/entropy/wiki/Method-7---Get-All-Building-Space-Areas) - Retrieve all building space areas
- [https://github.com/ubitech/entropy/wiki/Get-Building-SubAreas](https://github.com/ubitech/entropy/wiki/Get-Building-SubAreas) - Retrieve all subareas for a specific area
- [https://github.com/ubitech/entropy/wiki/Get-SensorDataStreams-per-building-for-a-list-of-attributes](https://github.com/ubitech/entropy/wiki/Get-SensorDataStreams-per-building-for-a-list-of-attributes) - Retrieve all data streams for a specific building space regarding a specific attribute
Users who can login to the platform can login with the same credentials to this Android application. All the registered buildings of the platform are shown in the application’s dashboard page. By selecting a building, the end user can see the last 30 values of consumption from that building. The application supports the following 3 types of recommendations: Tips – Quiz – Questions. Tips are notification messages where the application notifies the user about new tips. Quiz contain knowledge-based content and requires from the user to make a choice. Question is general-purpose content and requires from the user to make a choice. All the actions of the users regarding the provided notifications are rewarded with points. A summary page with points is made available for tracking current status and accomplishments of the user. A “Scan Location” functionality is also available where the end user posts in which building he has activity.

4.3 Software deployment guidelines

You can download this application from the android store. We provide 3 links, one for each instance. Upon selection of an instance, the android installation wizard process will start and a user-friendly installation process is going to be followed with minimal input required by the end user. The URLs are:

URL for POLO: https://play.google.com/apps/testing/com.bignerdranch.android.entropy13dec1248POLO
URL for UMU: https://play.google.com/apps/testing/com.bignerdranch.android.entropy13dec1248UMU
URL for HESSO: https://play.google.com/apps/testing/com.bignerdranch.android.entropy13dec1248

4.4 Main Usage Scenario/User Manual

Users who can login to the platform can login with the same credentials to this application as well. Following, the login Dashboard page is being displayed as shown in Figure 15.
Users can choose a building from the Dashboard page and view its consumption. In Figure 16 you can see an example.

![Building Energy consumption](image)

**Figure 16. Building Energy consumption**

Users can receive Notifications of type Tip and listed as shown in Figure 17 with content coming from the platform. After they open a tip a certain number of points is rewarded (points are defined by the administrator).

![Notifications and Tips](image)

**Figure 17. Notifications and Tips**

Users can receive Notifications of type Quiz, with content coming from the platform. After he opens a Quiz, the user is prompted to make a choice, according to which a certain number of points is rewarded (points are defined by the administrator). Points are rewarded after
providing the correct answer.

Figure 18. Quizzes and Questions

After interacting with the different type of recommendations, the user can find out about the collected Points and Badges.

Figure 19. Badges and rewards
This application can be translated into 3 different languages; in the Settings page (Figure 20), the user can select the most appropriate language.

Once the user is at an area within a registered building of the platform, using the option Scan location with QR Code (Figure 20) he can let the platform know about his location.
5. **Main Innovation Introduced by ENTROPY**

As already stated, ENTROPY is providing an innovative energy-aware ecosystem that can be easily deployable and applicable in smart buildings. In order to achieve so, **interoperability** and **extensibility** aspects are highly considered in the overall design of the proposed approach. Considering that most of the existing solutions in the market that are tackling energy efficiency in the buildings sector are associated with a set of constraints (e.g. usage of specific sensor networking equipment, support of part of network communication protocols, storage in customized format that do not facilitate data exchange, static definition of rules for recommendations), there was inherent a need for the design and development of a solution that can be interoperable with the multitude of the IoT devices, easily deployable and management as well as cost-effective.

The **main innovative characteristics** introduced by ENTROPY include:

- The design and implementation of **scalable sensor data monitoring mechanisms** supporting the aggregation of data streams coming from small and large-scale IoT deployments and exploiting the high performance in terms of data management by modern time series databases; such a characteristic is **crucial for guaranteeing the high-performance characteristics** of the produced platform.

- The conceptualization of **descriptive behavioural models** able to capture the behavioural characteristics of end users with regards to their energy consumption profiles; upon advanced behavioural profiling, personalised recommendations can be provided increasing the acceptance ration and, thus, the impact on energy efficiency.

- The design and development of **big data analytics mechanisms** for extracting energy and behavioural analytics that can feed the recommendation mechanisms; such analytics mechanisms are supporting the ease integration of analysis scripts provided by data scientists without imposing strict requirements on the usage of a specific analysis framework, revealing in this way the potential for integration of evolving analysis mechanisms.

- The design and development of a **user-friendly rule-based management system**, facilitating the straight-forward declaration of rules for sending personalised recommendations as well as their continuous evaluation and monitoring under real conditions.

- The **collection of continuous feedback from the end users through mobile crowdsensing mechanisms** and the support of self-learning and self-adaptation models with regards to the provided recommendations taking into account their daily interaction with the provided applications and games.

- The provision of an **easily deployable and manageable IT ecosystem** with small learning curve and operational overhead, facilitating its adoption by non-expert IT users in small offices and houses.

- The design and development of a set of **personalised applications and games** targeted for smart buildings, as well as **different profiles** (e.g. educational oriented, game play oriented).

- Augmented Reality Treasure Hunt game with ability to display measurement data in a real time, and includes different gamification elements in order to appeal to different types of users, taking into account their profiles and behaviour.

All the aforementioned aspects are provided through an integrated platform developed based on open-source technologies and the specification of open APIs for providing access to the deployed mechanisms.
6. CONCLUSIONS

In the current document, the software release of the final version of the integrated ENTROPY Platform is provided along with the final release of the developed serious game and personalized application. All of them constitute the main results produced within WP4 and regard a set, based on which an energy efficiency campaign in a smart building can be realized.

The detailed IT ecosystem can be easily deployable and applied in diverse cases with minimal configuration effort, the supported energy management and awareness services can be easily consumed while the design and development of further services and mobile applications is highly facilitated through the exploitation of open APIs. Guidelines for deployment and usage of the ENTROPY platform, the serious game and the personalized applications for software developers, IT administrators and end users are provided.
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