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Simulation of consumers and markets towards real time demand response

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Advantages of using RTLS and WSN to enable efficient power consumption

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Abstract

The use of Real Time Locating Systems is gradually spreading in different areas of society. Multiple sectors, such as industry, security or healthcare are already taking advantage of the benefits of knowing the exact position of people, animals or objects. Energy consumption can also be improved by the use of RTLS and thanks to these systems we can model the habits of users both at home and in public buildings. This information will create consumption maps based on the use of different electronic devices or the use of different spaces. Thus, the election of the best energy tariff or when the best moment is to use appliances will be an easier process.

Keywords: Real Time Location Systems, Wireless communication, Energy Consumption, Energy Tariff, Energy Savings

1. Introduction

Wireless Sensor Networks (WSN) are used for gathering the information needed by intelligent environments, whether in urban construction and Smart Cities, home and building automation, industrial applications or smart hospitals [*1*, *2*]. Wireless Sensor Networks support current requirements related to the deployment of networks that cover communication needs, and flexibly in time, space and autonomy, without requiring a fixed structure [*3*, *4*].

One of the most interesting applications for Wireless Sensor Networks is Real-Time Locating Systems (RTLS) [*5*]. Although outdoor locating is well covered by systems such as the current GPS or the future Galileo, indoor locating needs still further development, especially with respect to accuracy and the use of low-cost and efficient infrastructures.

On the other hand, energy consumption is one of the problems in which more efforts are being carried out. The efficient use of energy helps the sustainability of the planet and allows saving natural resources and reducing pollution.

Monitoring energy consumption is considered as a fundamental tool in optimizing the use of energy resources. In this sense, technology becomes a key tool to collect real-time information and present statistics from the energy consumed by any device.

Buildings and houses are places where the application of technologies for monitoring energy consumption will be more efficient due to the high energy costs associated with. The consumption of the appliances, points of light, air conditioning and heating boilers are critical points where energy leaks appear and their optimization reduces significantly the global energy consumption. Moreover, choosing the most favorable electricity tariff permits increase savings in energy consumption and reduce the cost for the users.

This paper presents the implementation how WSN and RTLS can help to optimize the energy consumption in houses and buildings by knowing the location of users and their behaviors while using energy.

The rest of the paper is structure as follows: Section 2 presents the background of the problem. After that, Section 3 presents how electrical energy consumption is in the residential Spanish market. Section 4 gives a brief description of how can energy consumption can be optimized by the use of RTLS and WSN. Finally, Section 5 presents conclusions and future work.

2. Background and Problem Description

T The optimization of energy consumption is one of the problems that most affect society and more efforts are being used to try to improve it. To this end, research and work make use of all kinds of techniques and technological advances. There are several key aspects to determine how and when energy is consumed in homes. On the one hand, it is necessary to know which devices are consuming energy. On the other hand, it is important to know the users' behavior in order to determine if they are making an effective use of the energy or if they are choosing the best moment to do it. WSN and RTLS have a great potential when used to get all the data to analyze consumptions, determine behavior patterns of the users or optimize the use of the energy in an automatic way.

There are several wireless technologies such as ZigBee, Wi-Fi or Bluetooth that enable easier deployments than wired ones, avoiding the need to wire buildings and decreasing the costs and drawbacks of the setup phase. WSNs make it possible to build a wide range of applications, such as control of energy costs, monitoring of environmental data, security and access control in buildings, as well as industrial and home automation, among many others. In this regard, telemonitoring (or sensing) allows to obtain information about users and their environment, which is taken into account when offering them customized services in line with their environment status. The building automation and control systems market has reached in the world of standards, protocols and data distribution systems, which allows building automation systems, such as security systems, lighting systems and others, to interact and integrate with each other [*6*]. The building automation and control systems which started with wired technology have now entered the era of wireless technology with the advent of technologies such as ZigBee, Z-Wave, EnOcean, and others. Not only building automation and control products have increased living standards and allowed for more convenient

lifestyles, they have also saved power through devices such as dimming systems and sensors. Among all the available products, security control has dominated the building automation and control market as a result of increasing concerns to enhance security. Furthermore, building automation & control systems can save up to 80% of power.

Furthermore, for the first time in human history, more people now live in cities than in rural areas, and in the next 20 years the urban population is expected to grow from 3.5 billion to 5.0 billion people [*7*]. The social, economic, environmental, and engineering challenges of this transformation will shape the 21st century. The lives of the people living in those cities can be improved – and the impact of this growth on the environment reduced – by the use of "smart" technologies that can improve the efficiency and effectiveness of urban systems. The smart city can be defined as the integration of technology into a strategic approach to sustainability, citizen well-being, and economic development.

Some of the applications of Real-Time Locating Systems include tracking people, assets and animals, access control, wander prevention, warning and alert systems, controlling security perimeters, or resources optimization. Companies need to use some sort of monitoring system to track their human and technical resources, and especially, to improve their security, efficiency and safety, and reduce occupational hazards. User identification is a key aspect for adequate services customization and environment interaction. This way, the system can identify each user, know where they are, and automatically provide them with services, without actually requiring the user to initiate the interaction. Knowing the exact geographic location of people and objects can be very useful in a wide range of application areas, such as industry or services. The advantage of knowing and visualizing the location of all the resources in a company and how they interact and collaborate in the different productive processes is a clear example of the demand for a platform that integrates location and automation features in a unique infrastructure. Another good example of this demand includes emergency situations where it is necessary to locate people, such as the case of forest fires or nuclear disasters. The development of a platform for remote location and automation that integrates different subsystems demands the creation of complex and flexible applications [*8*].

The scope of this work includes the use of RTLS and WSN that allow us to monitor the movements of users in their homes, in order to determine their behavioral patterns in relation to the use of appliances. With this data, we will be able to know when they are using a concrete appliance (e.g. the washing machine) and determine if it is the best moment according to the tariff rate.

Next Section presents how energy consumption is in the Spanish market. This information allows identifying the most susceptible consumptions to be optimized by the use of RTLS and WSN.

3. Energy consumption in the residential sector in Spain

The average consumption of a Spanish household is 10,521 kWh per year (0,038 TJ), being predominant in terms of final energy, fuel consumption, 1.8 times the electricity consumption. 62% of electricity consumption due to the electrical equipment, and to a lesser extent lighting, cooking and heating services and hot water. Table 1 shows in detail how this consumption is.

Table 1: Average energy consumption in a typical household in Spain.

	FINAL CONSUMPTION					
	Electrical	**Fuels**	**TOTAL**	**Electrical**	**Fuels**	**TOTAL**
Final use	TJ	TJ	TJ			
Heating	15.907	272.667	288.574	2,59%	44,38%	46,96%
Hot water	16.129	100.114	116.243	2,62%	16,29%	18,92%
Cooking	20.063	25.588	45.651	3,27%	4,16%	7,43%
Refrigeration	5.042	107	5.149	0,82%	0,02%	0,84%
Lighting	25.366		25.366	4,13%		4,13%
Appliances	133.468		133.468	21,72%		21,72%
Fridge	40.834		40.834	30,59%		30,59%
Freezer	8.083		8.083	6,06%		6,06%
Washing machine	15.812		15.812	11,85%		11,85%
Dishwasher	8.080		8.080	6,05%		6,05%
Dryer	4.469		4.469	3,35%		3,35%
Oven	11.022		11.022	8,26%		8,26%
TV	16.263		16.263	12,18%		12,18%
PC	9.906		9.906	7,42%		7,42%
Stand-by	14.292		14.292	10,71%		10,71%
Other equipment	4.707		4.707	3,53%		3,53%
TOTAL CONSUMPTION	**215.975**	**398.476**	**614.451**	**35,15%**	**64,85%**	**100,00%**

As can be seen in the following graphs (Fig. 1 and 2), there are some consumption that would be easily optimized through the use of WSN and RTLS. Among them, heating can be optimized by using a correct schedule depending on the hours when users are at home or even regulate its operation by areas depending on the occupation of spaces.

Other optimizable consumptions are the use of some appliances, by taking into account the day and the hour they are used, lighting by WSN and presence or location and the stand-by consumptions by the hours of charging of the devices.

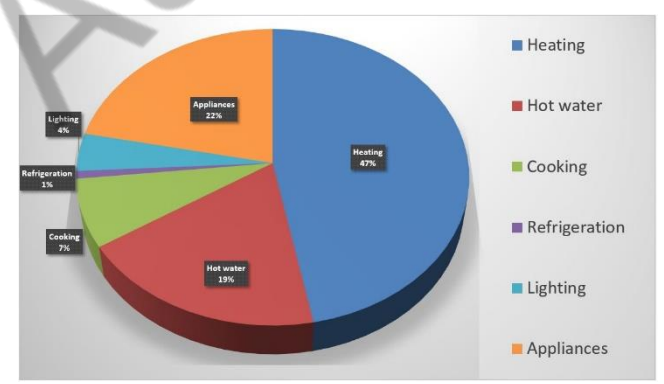

Fig. 1: Consumption by utilities in a typical household in Spain.

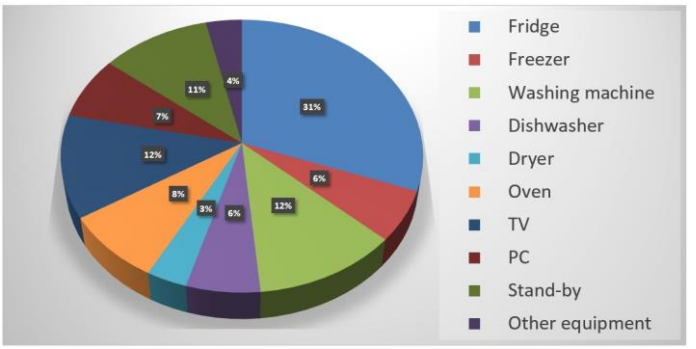

Fig. 2: Consumption by appliances in a typical household in Spain.

4. How do RTLS help?

RTLS are used for determining the position of a mobile element throughout the environment. This includes to locate people around their homes as we can see in Fig. 3. With this information we are able to know:

- When consumers are at home.
- Where consumers are into the household.
- What consumers are doing.

Moreover, the use of WSN permits to collect different information and to act over several elements, such as:

- Real-time meter monitoring implies knowing consumption in real-time.
- Light sensors to identify the level of natural lighting.
- Presence sensor, to turn off automatically lights or heating if there is no presence.

With this information, different patterns of users' behaviors inside their homes can be identifies. These patterns allow us to define schedules of staying at home, when cooking or laundry is done, what are the hours of rest or which rooms are not in use.

On the other hand, the electricity tariff rate in Spain changes every day and the energy has different cost depending on the day or hour it is demanded, as Fig. 4 shows.

Combining the information collected by the RTLS and WSN and the tariff rate, it is possible to improve the use of energy at homes by recommending users alternative hours and days to carry out some task scrollable in time (such as laundry or drying clothes) or avoid unnecessary consumptions by using automated switches.

All these things seem obvious, such as, control the stand-by at night. For example, if stand-by are reduced 100W, the savings are 100 W x 8 hours x 365 days = 292 kWh / year. According to the CNMC, the average domestic consumption in Spain is 2,630 kWh / year, so turning off the devices when sleeping implies savings of at least 10% of the annual consumption.

Fig. 3: Example of use of RTLS at home to determine positions and behaviors of users.

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
00:00	0,1193	0,1215	0,1198	0,1211	0,1216	0,1188	0,1149
01:00	0,1144	0,1170	0,1158	0,1183	0,1167	0,1146	0,1096
02:00	0,1139	0,1140	0,1135	0,1155	0,1148	0,1117	0,1076
03:00	0,1134	0,1133	0,1129	0,1155	0,1150	0,1115	0,1064
04:00	0,1125	0,1137	0,1126	0,1148	0,1144	0,1114	0,1065
05:00	0,1137	0,1151	0,1137	0,1144	0,1154	0,1120	0,1062
06:00	0,1204	0,1200	0,1195	0,1199	0,1211	0,1128	0,1075
07:00	0,1243	0,1252	0,1251	0,1225	0,1264	0,1126	0,1052
08:00	0,1275	0,1281	0,1285	0,1265	0,1285	0,1197	0,1089
09:00	0,1308	0,1305	0,1308	0,1291	0,1306	0,1231	0,1107
10:00	0,1304	0,1302	0,1303	0,1287	0,1300	0,1247	0,1116
11:00	0,1311	0,1303	0,1303	0,1287	0,1300	0,1262	0,1134
12:00	0,1300	0,1286	0,1283	0,1271	0,1285	0,1240	0,1118
13:00	0,1289	0,1286	0,1274	0,1261	0,1274	0,1245	0,1133
14:00	0,1269	0,1256	0,1245	0,1239	0,1255	0,1217	0,1125
15:00	0,1233	0,1229	0,1217	0,1210	0,1222	0,1146	0,1053
16:00	0,1230	0,1227	0,1215	0,1215	0,1220	0,1116	**0,1036**
17:00	0,1238	0,1239	0,1229	0,1228	0,1231	0,1115	0,1042
18:00	0,1259	0,1252	0,1248	0,1255	0,1245	0,1158	0,1113
19:00	0,1296	0,1280	0,1271	0,1280	0,1262	0,1196	0,1173
20:00	0,1322	0,1311	0,1300	0,1307	0,1290	0,1239	0,1234
21:00	**0,1356**	0,1347	0,1337	0,1340	0,1329	0,1292	0,1325
22:00	0,1311	0,1303	0,1296	0,1297	0,1295	0,1261	0,1304
23:00	0,1238	0,1230	0,1232	0,1238	0,1233	0,1183	0,1221

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Fig. 4: Electricity price in Spain depending on the hour and day of consumption.

Table 2 shows how much money can be saved at each home by optimizing the parameters outlined before. Although the savings may not seem relevant, if it is when you consider the volume of homes and the amount of energy wasted by misuse.

Table 2: Cost of use and savings of appliances energy consumption according to the Spanish electricity market tariffs..

	Consume (W/h)	Mx. Price	Av Price	Min. Price	Difference	Yearly
Price		0,1356 €	0,1196 €	0,1036 €		
Cooking	2.200	0,2983 €	0,2631 €	0,2279 €	0,0704 €	25,6960 €
Fridge	110	0,0149 €	0,0132 €	0,0114 €	0,0035 €	0,0000 €
Freezer	842	0,1142 €	0,1007 €	0,0872 €	0,0269 €	0,0000 €
Washing machine	1.050	0,1424 €	0,1256 €	0,1088 €	0,0336 €	6,9888 €
Dishwasher	1.148	0,1557 €	0,1373 €	0,1189 €	0,0367 €	5,7308 €
Dryer	270	0,0366 €	0,0323 €	0,0280 €	0,0086 €	1,7971 €
Oven	1.200	0,1627 €	0,1435 €	0,1243 €	0,0384 €	9,9840 €
TV	156	0,0212 €	0,0187 €	0,0162 €	0,0050 €	3,6442 €
PC	64	0,0087 €	0,0077 €	0,0066 €	0,0020 €	2,9901 €
Iron	1.200	0,1627 €	0,1435 €	0,1243 €	0,0384 €	3,9936 €
Hair dryer	1.875	0,2543 €	0,2243 €	0,1943 €	0,0600 €	6,2400 €
						67,0646 €

5. Conclusions and Future Work

The present text explains how RTLS and WSN can help to monitor consumptions and to identify users' habits and behaviors. With that data and information, new models of analysis can be design and developed. This models allow to improve the use of energy and avoid unnecessary consumptions.

However, the most important point of all the issues discussed above is aware users of the efficient use of energy at optimal times and promote environmentally friendly habits.

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