Analysis and calculation of energy efficiency of radio beacons Internet of Things (IoT)

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Abstract. The paper examines one of the most relevant trends in the development of information technology Internet of Things (IoT). The analysis and calculation of the energy efficiency of the IoT solutions sensors are carried out. The key characteristics of assessing the durability of the sensors are investigated.

1. Introduction
Many smart devices are connected to the global network every year. The Internet of Things is developing rapidly and by 2025 75.45 billion technical devices are predicted to connect to the Internet of Things. Technologies such as the Internet of Things, radio frequency identification (RFID), wireless sensor networks (WSN), machine-to-machine communications (M2M), short-range communications (NFC), and others have fully found their place in this area. IoT refers to the digital interconnection between the Internet and everyday objects. These so-called connected objects are sensitive to the environment through sensors (temperature, position, etc.), which are already an integral part of various areas of society (smart home, smart city, smart medicine, etc.) [1]

The official definition of the Internet of Things is given in ITU-T Rec. Y.2060, according to which the IoT (English Internet of Things) is the global infrastructure of the information society, providing advanced services by organizing communication between things (physical or virtual) based on existing and evolving interoperable information and communication technologies [2, 17, 18].

In other words, IoT touches all related objects. They can be connected through their sensors to the Internet through a computer, mobile phone, applications, or any other means of communication. They are associated with computer systems, people, or devices [13-16]. They are called connected and smart objects because they communicate and interact with each other in real-time and collect information about their use.

2. Materials and methods
A coin cell battery is a small battery this is one of the most common batteries that powers many everyday items such as calculators, small remote controls, watches, and toys. It is also used for hearing aids and wireless alarms, so it is ideal for stand-alone devices as they generate very low currents for a long period of time.

This battery has a very long lifespan, but it still depends on how it is used. Example: A button-cell battery on a child's toy will not last long compared to a remote control or watch. From the point of view of aesthetics, it is a thin round disc [3, 9].
Although most of them look the same, button batteries come in different sizes and materials (lithium button batteries, alkaline button batteries, silver oxide button batteries, zinc air batteries). The type of battery that we will study in this part of the work is a lithium battery (3 V) and is indicated by the CR icon [4, 10-12].

3. Results and Discussion
Abbreviations are defined by the International Electrotechnical Commission as the so-called IEC classification. The first letter denotes an electrochemical device, the second letter denotes a round cell, the first number denotes the cell diameter in millimeters, and the last number denotes the cell height in tenths of a millimeter (CR2016 20 mm 1.6 mm lithium manganese dioxide, CR2032 20 mm 3.2 mm lithium-manganese dioxide, CR2025 20 mm 2.5 mm lithium-manganese dioxide.) [5, 19-20].

Nowadays, these batteries are becoming more and more important on the Internet of Things. An IoT device usually has a limited number of Protocol Data Units (PDUs) that it can send before the battery reaches the point where it cannot connect until electricity is restored or replenished. Some of the most popular CR battery brands and details of each battery are shown in Table 1 [6-8]:

| Designation | CR2430 | CR2354 | CR2032 | CR2025 | CR2016 |
|-------------|--------|--------|--------|--------|--------|
| Form        | Coin   | Coin   | Coin   | Coin   | Coin   |
| Technology  | Lithium| Lithium| Lithium| Lithium| Lithium|
| Capacity (mAh) | 270-290 | 560    | 225    | 160    | 90     |
| Voltage (V) | 3      | 3      | 3      | 3      | 3      |
| Height (mm) | 3.0    | 5.4    | 3.2    | 2.5    | 1.6    |
| Diameter (mm) | 24.5  | 23     | twenty | twenty | twenty |
| Weight (gr) | 2      | 5.8    | 2.5    | 2.3    | 1.8    |

Depending on these 5 batteries, selected (CR2430, CR2354, CR2032, CR2025, and CR2016) in the table above, suppose the iBeacon protocol is advertised within 600 ms, the packet length is \( l_p = 34 \) bytes. The beacon electronics consume \( I_m = 50 \) \( \mu A \) at \( U_m = 3 \) V. Now we can predict the beacon lifespan and transmission efficiency:

**CR2430**

The device (IoT) uses a CR2430 battery with the ratings shown in Table 2.

| Package length \( l_n \) | 34 byte |
|--------------------------|---------|
| \( E \) (Battery capacity) | 290 \( \mu A h \) |
| \( U \) (Battery Voltage)  | 3V      |
| \( I_m \) (Beacon current) | 50 \( \mu A \) |
| \( T \) (Signal emission period) | 600 ms |

Energies in joules: \( E = 1V \times 1A \times 1s = 1 \) J; \( (1) \)

The battery capacity is the product of the discharge current of the battery (in amperes or mA) by the discharge time in hours.

Let’s perform the calculation information transfer rate \( v \) according to the formula:

\[
v = l_n \times \left[ \frac{1}{T=600 \text{ ms}} \right] \times 3(\text{channel}) \times 8 = 1360 \left[ \frac{\text{bit}}{s} \right]; \quad (2)
\]
Let's perform the calculation power consumption of the beacon \( W_m \) according to the formula:

\[
W_m = l_m \ast U_m = 50 \, [\mu A] \ast 3 \, [V] = 0.15 \, [mW];
\]  \hspace{1cm} (3)

Let's perform the calculation energies per bit \( E_{bit} \) according to the formula:

\[
E_{bit} = \frac{W_m}{V} = 0.15 \left( \frac{mW}{V \, (bit/\delta)} \right) = 0.11 \, [\mu J/bit];
\]  \hspace{1cm} (4)

Let's perform the calculation energies per advertisement according to the formula: \( E_{adv} \)

\[
E_{adv} = E_{bit} \left( \frac{\mu J}{bit} \right) \ast l_n \ast 8 = 29.92 \, [\mu J/advertisement]; \hspace{1cm} (5)
\]

Let's perform the calculation stored energy by the battery \( E[J] \) according to the formula:

\[
E[J] = E[mAh] \ast U[V] = 290 \, mAh \ast 3V = \frac{290 \times 3600}{1000} \, [A] \ast 3 \, [V] = 3132 \, [J]; \hspace{1cm} (6)
\]

Let's perform the calculation battery life according to the formula: \( t_{bat} \)

\[
t_{bat} = \frac{E[J]}{E_{pe} \ast \left( \frac{1}{\delta} \right) \ast 0.7} = \frac{3132000000}{29.96 \left( \frac{1}{0.6} \right) \ast 0.7} = 43 \, 965 \, 240 \, s = 509 \, days = 1.32 \, year. \hspace{1cm} (7)
\]

Similar calculations were performed for the remaining four storage batteries shown in Table 3. The calculation results are shown in Table 3.

| Battery type | Service life (year) |
|--------------|---------------------|
| CR2016       | 0.43                |
| CR2025       | 0.77                |
| CR2032       | 1.08                |
| CR2430       | 1.32                |
| CR2354       | 1.55                |

For clarity, using the excel program, the calculation results are shown in Figure 1.

![Figure 1. Lifetimes of CR batteries](image-url)
4. Conclusion
M2M technology also plays an important role in the IoT. The Internet of Things relies on pre-existing tools (computers, phones, etc.) and M2M technology to deliver its services. One of the most common IoT applications is Bluetooth Low Energy (BLE) beacons. One of the goals of IoT is to use smaller devices with longer battery life. In subsection 4.4 of the thesis, calculations were made to assess the service life of 5 CR batteries.

The following conclusions can be drawn:
1. The most popular for the Internet of Things is the lithium battery, which consumes 3 volts. During our calculations for each battery, it was observed that a battery with a larger capacity has a longer life span. Battery life also depends on its use. The more it is used, the faster it degrades.
2. M2M technologies play a very important role in the Internet of Things, in particular, providing the necessary network infrastructure. Telecommunication technologies (GPRS, 4G, 5G) are used to enable machines to communicate over long distances. To integrate globally, the Internet of Things hosts its information in the cloud.

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