El-watch's Neuron power usage

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Abstract

This article aims to give a short overview over the power usage of El-watch's Neurons, and give an independent estimate to the Neurons lifetime. The estimate claimed by El-watch themselves is around 15 years. We find the claim to be reasonable, but also includes a best-worst case scenario. The best case scenario, where the neuron never sends any data other than once every two minutes, gives a lifetime of 21.8 years. The worst case scenario, where the neuron sends data every two seconds, gives a lifetime of 1.8 years. A test period of 30 minutes with a good connection gave a lifetime of 21.2 years, and a test period of 20 minutes with a poor connection also gave a lifetime of 21.2 years.

Keywords: El-watch, Neuron, power usage, energy

1. Procedure

A Neuron air temp sensor was opened, and it's battery was soldered off. An Otii Arc was used to power and measure the current flow of the Neuron. We collect some data of the Neurons power use, and from that data, we calculate an average nAh of ten, two second segments of sending data and ten, two seconds segments of not sending data. From there, we can estimate theoretical best and worst case scenarios. In addition to this, we will perform one 30 minute test with good connection, and one 20 minute test with poor connection. The test with poor connection will be done 100 meters away from the router, in all other tests, the distance is less than 5 meters.

2. The Tests

The Neuron's flowchart is believed to be similar to figure 1.

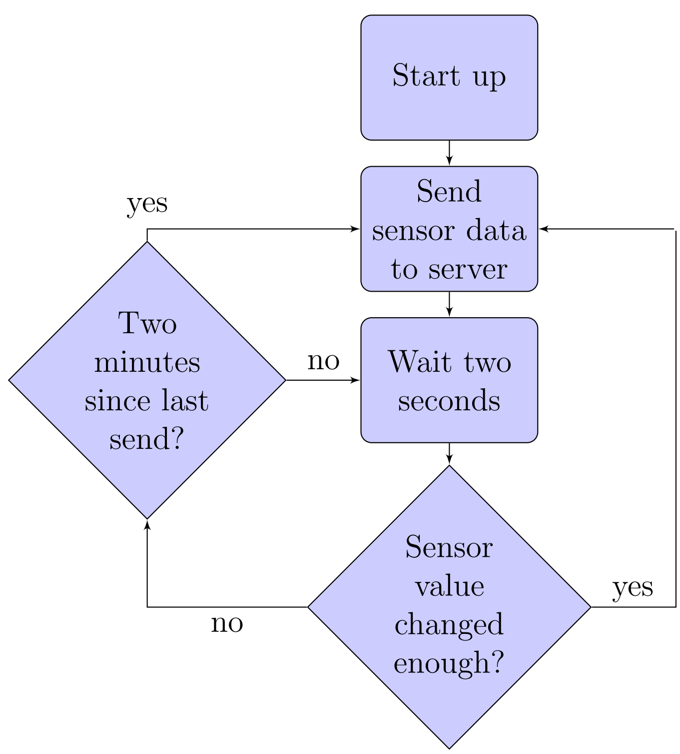

Figure 1: Neuron flow chart

There are three actions that require a significant amount of energy, start up, sending data, and checking if the value has changed significantly[1]. The start up normally only occurs once and will therefore be ignored. Just to be clear, it should be stated that the send action is composed of the check action and sending.

2.1. Average energy for checking value

In figure 2, we see the Neuron checking it's sensor value, waiting two seconds, then checking again (We also observe a small spike in the middle, but are unsure as to what this could be). The two large spikes seen in figure 2, and all spikes in power use that come from checking the sensor value will be referred to as "checking spikes". Similarly, spikes from sending data will be referred to as "sending spikes".

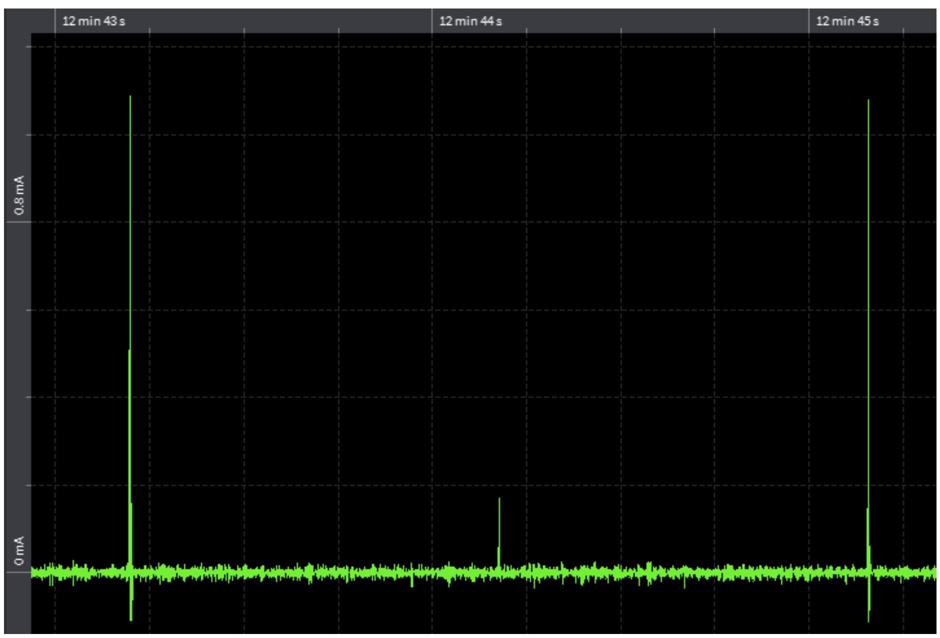

Figure 2: Energy for checking sensor value

[1]Neurons have decimal value accuracy for temperature and other measurements. This creates insignificant changes quite often. These small fluctuations *do not* trigger a send action.

See table 1 for ten of these two second segments (One checking spike per segment). Averaging these numbers gives us an average energy and time of

Energy nWh	Time s
3.31	1.97
3.34	1.96
3.39	1.97
3.39	1.97
3.28	1.96
3.34	1.97
3.32	1.94
3.19	1.97
3.21	1.96
3.29	1.96

Table 1: Power from one checking spike to another

3.30 nWh and 1.96 s. We know that the battery supplies 3.6 V, so we can find the current per hour by

$$\frac{3.30\,\mathrm{nWh}}{3.6\,\mathrm{V}} = 0.92\,\mathrm{nAh} \tag{1}$$

The battery the Neuron comes equipped with supplies 400 mAh. That is enough energy to power the checking spike

$$\frac{400\,000\,000\,\mathrm{nAh}}{0.92\,\mathrm{nAh}} = 434\,782\,608 \tag{2}$$

435 million times. Since this sequence takes on average 1.96 seconds, we find that if the Neuron *never* sent any data, it would have a lifetime of

$$434\,782\,608 \times 1.96\,\mathrm{s} = 852\,173\,913\,\mathrm{s} = 27\,\mathrm{years} \tag{3}$$

27 years.

2.2. Average energy for sending data

In figure 3, we see the neuron sending data, waiting two seconds, checking sensor value, waiting and then checking again. See table 2 for ten, two second segments, from a sending spike to a checking spike, including only

Figure 3: Energy for sending sensor value

the sending spike. Averaging these values gives us an average energy and time of 50.8 nWh and 1.98 s.

Energy nWh	Time s
46.9	1.97
44.3	1.98
62.4	1.98
52.8	1.98
62.1	1.96
52.6	1.97
42.4	1.97
47.4	1.98
43.8	1.98
53.5	1.98

Table 2: Power from and including a sending spike up until a checking spike

Now, doing exactly the same calculations as in section 2.1,

$$\begin{aligned} \frac{50.8\,\text{nWh}}{3.6\,\text{V}} &= 14.1\,\text{nAh} \\ \frac{400\,000\,000\,\text{nAh}}{14.1\,\text{nAh}} &= 28\,368\,794 \\ 28\,368\,794 \times 1.98\,\text{s} = 56\,170\,212\,\text{s} &= 1.78\,\text{years} \end{aligned} \tag{4}$$

we find that if the neuron were to send data every two seconds, it would have a lifetime of almost two years.

3. Best and worst case scenario

In theory, the neuron could be sending data every two seconds. For example, the light sensor could be attached to a blinking light on a server, or placed behind a light and a very slow fan. These are by no means likely situations, and would probably never occur if draining the battery was not the aim. However unlikely or not, the worst case scenario is only 1.7 years.[2] The best case scenario is not the 27 years mentioned at the end of section 2.1, since even if the value never suddenly changes during the course of 27 years, the sensor still sends data once every two minutes. To find the best case scenario, we assume the Neuron performs 59 value check actions, and one send action. This gives us an energy and time of

$$\begin{aligned} 0.92\,\text{nAh} \times 59 + 14.1\,\text{nAh} &= 68.4\,\text{nAh} \\ 1.96\,\text{s} \times 59 + 1.98\,\text{s} &= 117.62\,\text{s} \end{aligned} \tag{5}$$

14.1 nAh and 117.62 s. Performing the same calculations as in section 2.1 and 2.2, we find

$$\begin{aligned} \frac{400\,000\,000\,\text{nAh}}{68.4\,\text{nAh}} &= 5\,847\,953 \\ 5\,847\,953 \times 117.62\,\text{s} = 687\,836\,257\,\text{s} &= 21.8\,\text{years} \end{aligned} \tag{6}$$

that the best case scenario gives the Neuron a lifetime of 21.8 years.

[2] El-watch mentions that when put in a freezer, the neuron might only last 6-7 years as apposed to 15. Therefore, one might even argue that the worst case scenario should be half the lifetime first suggested, so only 0.8 years or 9.6 months

4. More testing

We found a best and worst case scenario lifetime, 21.8 and 1.7 years respectively. Intuitively, the worst case scenario seems so unlikely, that estimating 15 years, instead of a flat middle value of 10 years seems reasonable. Additionally, due to the fact that the Neuron only updates (other than once per two minutes) on significant changes, and that most environments hardly ever change quickly enough to demand additional send actions[3], the best case scenario is actually quite likely. However, we can support this with some additional testing.

First, we want to support our method of finding an average value for sending and checking the sensor value. Over 30 minutes, the sensor had the same type of pattern we attempted to recreate when finding the best case scenario: 59 value check actions and one send action. The Neuron used 3870 nWh over this period. This gives the Neuron a lifetime of 21.2 years, very similar to our best case scenario result (We will skip showing math of this process from here on out). From this we can gain confidence in our averaged energy per action values to give us accurate, and perhaps slightly generous estimations for a Neurons lifetime.

Now, using our own database with a resolution of 6 seconds, we can see how many times the sensor had to update outside of the expected once per two minutes by finding how many data points fall within a week, and subtracting the number of minutes there is in a week divided by two. There are 10080 minutes in a week, so we should expect to see slightly more than 5040 data points. It turns out there are significantly less. See table 3 for details.

As of yet, we are unsure as to why there are so few data points, and even more so in the case of the humidity sensor. We suspect that there is simply some chance of loosing the data somewhere. While monitoring the power usage, one instance of a "double send" was recorded. Regrettably the data the image from figure 4 was taken from is lost, and so there are no labeled axis, however, we noted that the spike was twice as large as a normal send spike. The double send spike required 147 nWh, whereas a normal spike only needed 70 nWh.

We would expect that the Neuron has some number of maximum send at-

[3] A realistic example of this not being the case might for example be temperature inside, close to a busy exit door during winter. But even this scenario would have ideal conditions during closed hours or when the outside has the same temperature as inside.

Sensor name	Data points in a week
Magnet 1	4671
Magnet 2	4876
Light	4700
Surface temp 1	4797
Surface temp 2	4643
Humidity	3213
Air temp 1	4854

Table 3: Number of data points in a week from various sensors

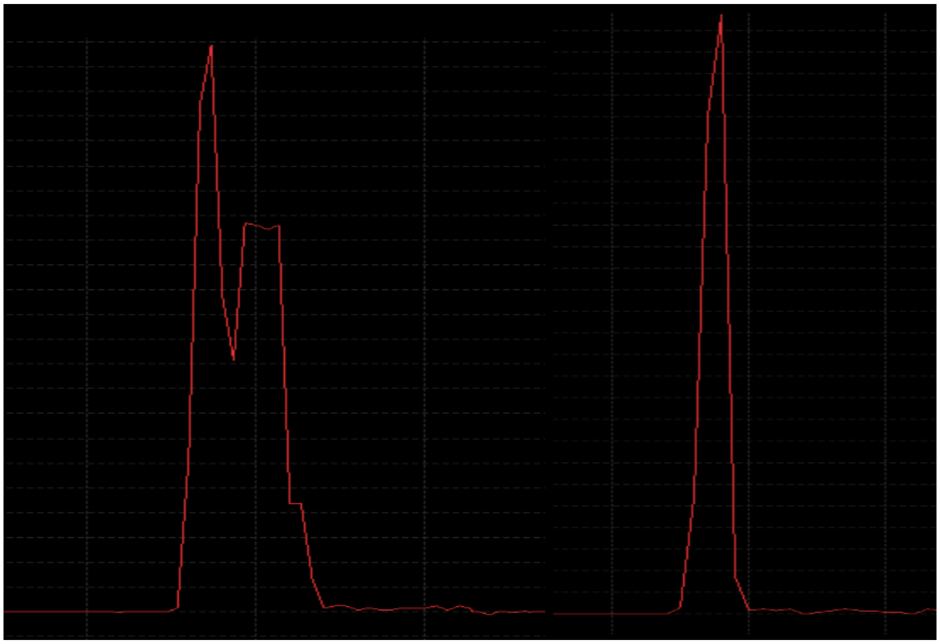

Figure 4: A "double send" next to a normal send action

tempts, and perhaps this is where the data is lost. More research is needed to determine where the source of the problem is or if these results are somehow intentional.

Now, we will do a 20 minute test period over a long distance. We would expect to see that the sensor uses more energy than when it is very close to its router. The sensor's limit was at approximately 100 meters, with various walls between. There, over 20 minutes, it used 2590 nWh, giving it a lifetime of 21.2 years , just like the 30 minute test with good connection. This result would indicate that the sensor does not spend less energy when close, nor more energy when far from the router to transmit data.

5. Conclusion

We primarily used two methods for finding the expected lifetime of the Neuron. The first method was to determine the energy cost of each action, then create a theoretical scenario with a certain combination of actions, and calculate the lifetime accordingly. This was useful for finding a worst case scenario. We also measured the energy use over a 30 minute period, and by assuming that period was representative of the rest of it's life, found an expected lifetime. The best case scenario and the 30 minute period gave similar results, and therefore support each other.

El-watch promises 15 years of life. From the testing we have done, we believe that to be a very fair estimation (Assuming the sensors are not turned long before the user receives them). Yet, it is worth mentioning, that under certain conditions, even though very unlikely to occur by misfortune, the Neuron could probably be drained of power within a year if actively stimulated in a cold environment.