Wireless Energy Harvesting

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Abstract

There are many different approaches to harvesting small amounts of ambient energy nowadays. In this paper we are going to concentrate on two of those technologies, namely PoWiFi[2] wireless power and Power harvesting from microwave oven leakage [4].

Introduction

Wireless technology is widely used and well established for TV, Internet and Telecommunication. But data transportation is just one application of this technology. The next step and topic of this paper would be to use wireless energy transmission to different electrical devices. In the last few years power requirements for small electrical devices have steadily decreased. For example the energy consumption of a cooking thermometer can be as low as 23.9 μW. If the trend of making electrical devices more efficient continues this way, the possibility of using ambient energy harvesting to power said devices is getting more and more feasable.

First we are going to take a look at PoWiFi[2]. A Combination of hardware and software that tackles the problems of delivering power over WiFi, such as the energy leakage during silent periods of WiFi transmissions and the fact that wireless charging should not interfere with normal packet traffic.

In "Power Harvesting from Microwave Oven Electromagnetic Leakage" [4] they abuse the fact that most commercial microwave ovens are leaking power when used. This leakage can be transformed into electric energy by using special antennas. This way it is possible to harvest enough energy to power small electrical kitchen devices while using energy that otherwise would go to waste.

Power over Wifi

Harvesting– The main idea behind using Wifi to harvest energy is that it is obviously wire-free and it is present nearly everywhere in our homes these days. In the paper "Powering the Next Billion Devices with Wi-Fi"[2] they found a way to convert Wifi-signals sent by routers into direct current (DC) to power some temperature sensor within a range of 10 feet. To do so they had to develop a multichannel Radio Frequency (RF) harvester to convert alternating current radio signals (AC) into a minimum of 1.8-2.4 V DC to be able to power microcontrollers, sensor systems, etc. 1 and a prototype PoWifi router.

The router consists of Asus RT-AC68U router with three 4.04 dBi antennas operates on three non overlapping channels (1, 6 and 11). It is configured in a way, that the router queues up power packets, in addition to normal data packages, in case the amount of frames in the queue is to low (below 5) to supply the sensors with enough energy. A big challenge when doing this is to not influence the normal data traffic to much.

The harvester converts the 2.4GHz signal into DC voltage and boosts that voltage with a DC to DC converter, with a minimum input voltage threshold of 300mV. A problem was that if they are just focusing on one channel they were getting not enough energy to power the sensor, because if there is no traffic on this channel for a moment then they wouldn't be able to get any energy out of it. Second thing is that they would produce a high level of interferences on one channel, so they started to listen onto three different channels. These three channels had to be non overlapping to reduce the levels of interferences to a minimum and to get a higher probability that there is some traffic they are able to get power from.

Experiment– The goal of the experiment was to determine how much energy can be harvested by a Wifi router within 3 m range and that it will not noticeably affect page loading times on the user side. At first they build a battery free temperature sensor and a camera which were placed on different distances. As the experiment shows the camera and the sensor were able to operate battery free within 5 and 6 m far from the router. To have an evidence if the battery systems are working or not, every time they run, they will collect data and send it to a Universal Asynchronous Reciever Transmitter (UART) interface. As a next step they added some batteries to the camera and the sensor, as a result the sensors where able to run up to a distance of 8.5 m. As a last experiment the PoWiFi-router was tested in real world conditions in six different homes in a metropolitan area for 24 hours. In this experiment they also tested four different schemes(Baseline, BlindUDP, PoWiFi and NoQueue) to find out which effects they have on the Wifi clients.

- Baseline: Just the router without extra traffic.
- BlindUDP: UDP broadcast traffic at 1 Mbps to maximize its channel occupancy.
- PoWifi: UDP broadcast traffic at 54 Mbps with threshold check.
- NoQueue: UDP broadcast traffic at 54 Mbps without threshold check.

They came to the conclusion, that PoWifi has no noticeable effects on UDP, TCP traffic or the Page loading time (PLT) on the client side.

Reasons for usage– First of all nearly every household and office these days has its own WiFi router, so why not use the power of packages which would be lost anyway to power our devices. Next thing is that we wouldn't rely on having a socket in the environment to power up our devices and we would be able to get rid of any wires.

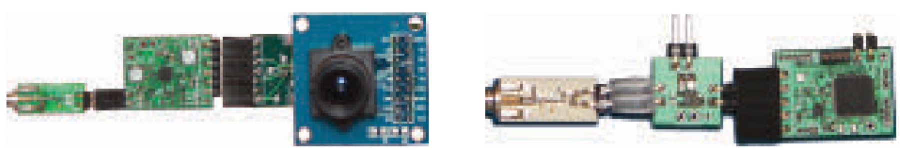

Figure 1: PoWiFi's battery free camera and temperature sensor design [2]

Power from Microwave leakage

Harvesting– In comparison, instead of using Wifi for harvesting energy, in the paper "Power Harvesting from Microwave Oven Electromagnetic Leakage" [4] they found a way to use leaking energy of microwave ovens to recieve energy. It is possible to harvest power in close vicinity (5 - 20 cm) to a microwave door while it is running. By using a rectenna, consisting of a dipole antenna and a charge pump, they managed to convert the leaked power to usable direct current(DC). When choosing a fitting dipole antenna there is always a trade off to be made. To reach a higher energy gain the antenna has to have narrower angular beams. According to [4] for harvesting microwave leakage, a wider angular beam is neccessary. A Dickson charge pump converts AC electrical power from a lower voltage to a higher, usable DC voltage using a network of capacitors and diodes. There are multiple reasons why using such a rectenna is good. On one hand the very low manufacturing cost due to its inexpensive components and on the other hand it is small enough to fit into most devices.

Experiment– The goal of the experiment was to find out how much energy could be harvested from microwave leakage. At first two types of charge pumps were tested to determine the one with the highest conversion efficiency. After some testing a Dickson charge pump optimized for 10kΩ turned out to work best with a conversion efficiency of 70%.

The next series of experiments have been performed to determine the amount of Power that can be harvested by such a device. Over a timespan of 2 minutes at distances of 5, 20, 50, and 100 cm the amounts harvested were 540, 126, 42, and 6 μW, respectively. Figure 2 shows the power consumption of two small kitchen devices to bring those numbers into perspective. The tests have also shown that the possible amount of energy that can be harvested varies heavily depending on distance from the oven, cooking time and even the contained food.

Reasons for usage– (1) Harvesting leaking power from microwaves would use energy that would be wasted otherwise. (2) Most households own a microwave and usually there are a lot of low power devices in kitchens. (3) The required rectennas are inexpensive to make

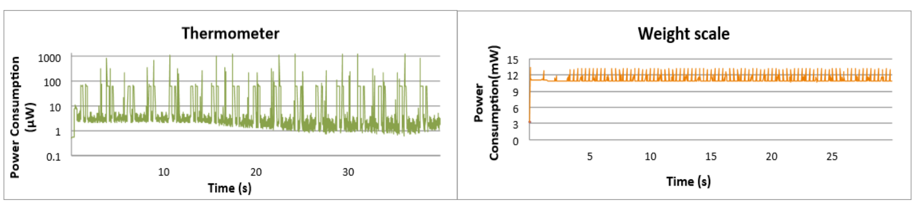

Figure 2: Power consumption of different kitchen devices.[4]

Possible applications

If we would be able to get rid of every cable needed to power things, this would very comfortable for everyone. Just imagine if u sit in your office and your phone is low on battery, you then just connect to a router and your phone starts charging without any cable so you are still able to move around. But that's only the peak of the iceberg, just think about different applications in the medical sector, where we from now on would be able to use micro sensors and cameras for medical treatment.

There are a few companies working on this idea to become true for everyone. For example 'Energous' is one of the first companies to develop a wire-free charging technology called 'WattUp'[3]. With this technology they hope to be able to charge a wide variety of electronic devices like smartphones, cameras, LED lights, toys and so on.

The basic idea behind their technology is that they have a transmitter, or so called 'Power Router', which tracks the devices to be charged and sends concentrated Radio Frequency signals to the devices direction. Those RF-signals will then be converted into battery power by the device itself. At the moment you will be able to move around at distance of up to 15 feet from the transmitter.

Although Wattup is working it does not fulfill the FCC limitation[1] of 5.8GHz and 1W total for wireless transmission and therefore will not get approval any time soon.

Conclusion

Both of the above technologies have shown the feasability of harvesting ambient energy in their respective ways. PoWiFi was able to operate wireless cameras and temperature sensors with or without batteries using their hardware software combination and harvesting power from microwave leakage can charge small electrical devices in close vicinity, but non of them can offer a commercially practical solution. All that said, there are loads of different approaches to wireless power transmission but we still have a long way to go to reach the dream of wireless energy for everyone.

References

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[2] Benjamin Ransford Saman Naderiparizi Joshua R. Smith Vamsi Talla Bryce Kellogg and Shyamnath Gollakota. "Powering the next billion devices with wi-fi". In: *Proceedings of the 11th ACM Conference on Emerging Networking Experiments and Technologies* (2015).

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[4] Kawahara Yoshihiro et al. "Power harvesting from microwave oven electromagnetic leakage". In: *UbiComp '13 Proceedings of the 2013 ACM international joint conference on Pervasive and ubiquitous computing* (2013).