Low Power but High Energy: The Looming Costs of Billions of Smart Devices

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Abstract

Individually, wall-powered Internet of Things devices are small: in form factor, in complexity, in function, and in power draw. However, at scale, and certainly at the scale optimistic forecasters project, these small devices add up to be a big energy problem. Just adding a single two watt sensor to each US building would add to more annual energy consumption than some small countries. Wall-powered IoT devices are also easier to create than their energy-constrained (i.e. battery-powered) counterparts, and marketed as more convenient (no hub required!), leading to their continued growth. Yet, unlike other energy consuming devices, there are no Energy Star (or equivalent) standards for smart devices. Despite having very infrequent active times, they draw power for functions like AC-DC conversion, wireless communication, and wakeup word detection continuously. Further, the discrete nature of devices and siloed nature of IoT ecosystems leads to significant redundancy in IoT devices.

We posit that new techniques are needed to reverse this trend. This includes new techniques for auditing devices, systems that leverage existing devices rather than requiring new ones, and architectures that have less reliance on the cloud (and the energy overhead of network usage and cloud compute). The IoT is pitched to improve energy efficiency and reduce users' carbon footprints, but we need a new research agenda to ensure the devices themselves are not the next problem.

1 Introduction

Decades of research into low power wireless embedded systems has made ubiquitous battery-powered devices possible. Recognizing the negative impacts of disposable batteries [13], research continues to lower power requirements further, making devices low power enough to operate on scavenged energy [11]. The underlying motivating intellectual challenge has been how to make increasingly interesting and useful computers operate with increasingly less energy. When energy is *not* constrained, however, even for Internet of Things (IoT) and other embedded devices, the research questions shift as managing limited energy is no longer the pressing concern. Mains-powered devices do not have to fret over every last joule, instead relying on stable power from the grid. And, as even carelessly implemented mains-powered devices still likely only draw a handful of watts, individually they pale in comparison to the energy consumption of other common loads. This has kept wall powered IoT devices under the radar from an energy consumption perspective.

But, the Internet of Things is plural for a reason, and the key value proposition has always been its purported scale. This has unfortunate implications for sustainability: while an individual mains-powered device may consume a relatively insignificant handful of kilowatt-hours of electricity per year, at national or global scale, the consumption adds up. Consider: a popular commercially available air quality sensor draws just 1.76 watts in normal operation [3]. As the COVID-19 pandemic has highlighted, monitoring indoor air quality is a pressing need, but deploying just one of these sensors per building in the US's 5.6 million commercial buildings [1] would add 237 MWh of energy consumption, *per day*. Annually, this is more energy consumption than some small countries [2].

Additionally, the IoT revolution has reversed the continuously improving power trend for certain appliances by making them "smart". For example, energy star requirements and technology advances dramatically lowered the power draw of televisions, but adding connectivity and additional features has increased their standby consumption [14]. Similarly, traditional light bulbs are physically disconnected when turned off, whereas smart bulbs constantly draw a trickle of energy to remain networked whether used or not [26]. Introducing always-on voice assistants is another new source of continuous energy consumption in an IoT-enabled world.

Using an AC-DC converter to power IoT devices provides simplicity and reliability, but it comes at the cost of adding an additional, albeit small, load to the electrical grid. Reducing energy consumption of buildings is a key national priority [4],