Horizon Scanning Series

The Internet of Things

Energy Implications of the Internet of Things

This input paper was prepared by Rod Tucker

Suggested Citation

Tucker, R (2019). Energy Implications of the Internet of Things. Input paper for the Horizon Scanning Project “The Internet of Things” on behalf of the Australian Council of Learned Academies, www.acola.org.

Energy Implications of the Internet of Things

Rod Tucker, University of Melbourne

Introduction:

The conventional Internet is often regarded as the largest human-made structure, but as the Internet of things (IoT) grows in span, capacity and complexity, it will eventually dwarf the Internet. By 2050, the number of IoT devices in Australia could reach 3 billion or more – orders of magnitude more than are connected to today's Internet. All these devices will require connectivity and they will all consume energy. This raises the question of how large the total energy consumption of the IoT could become and its impact on Australia's energy supply.

Recent studies have shown that the communications infrastructure underpinning the Internet and its connected devices, together with the data centres and servers that manage information flow, currently consume 2 – 5 % of electricity supply in countries such as Australia.[1,2,3] It is likely that devices connected to the IoT, will, on average, consume less energy than their Internet counterparts, but this will be offset, to a degree, because there will many more of them. Similarly, the IoT communications infrastructure will typically carry less data than the Internet, but it will need to communicate with more devices than the conventional Internet and these devices will be spread more widely.

What will be the energy consumption of a fully operational IoT? Will it compare to the conventional Internet, or could it consume even more energy? It is very difficult to provide definitive answers to these questions, but it is useful to understand what are the key factors that affect the energy consumption of the IoT.

Structure of the IoT:

For this analysis, we divide the IoT into three main components: (a) the IoT devices that collect data and carry out actions, (b) the communications infrastructure that manages information flow between the devices and data centres, where the data is processed, and (c) the data centres.

Devices: Devices connected to the IoT perform sensing and actuating functions such as environmental monitoring, traffic flow monitoring, and irrigation control. The energy consumption of each device depends on factors such as the complexity of the computations the device performs, the ratio of the time that it is active performing tasks to the time that it is inactive, and the amount of data it sends and receives.

In many devices, energy consumption is dominated by the process of communication data to and from the device, either by wired connections or by wireless technologies.[4] Wired and wireless connections use a variety of standardized technologies such as Ethernet, Zigbee, WiFi, and 5G. Wireless connections typically consume more energy than wired connections because in a wireless communications system the transmitted radio signal spreads over a wide area and most of its energy is lost. On the other hand, a wired connection ensures that the transmitted energy is directed to the desired location. It is likely that communications with devices in the IoT will be dominated by wireless owing to the very large number of devices to be connected and the fact that they will be widely dispersed.

Powering Devices: Every device in the IoT will require a source of energy. For devices in factories, offices and homes, this power will typically be obtained via the conventional power network. But devices located away from conventional power sources, other means of powering are needed. One solution is to use batteries in each device. This approach has obvious undesirable environmental implications – even if a battery lasts for a year or more, the number of batteries to be disposed of each year on a global scale could become enormous. There is also a practical limitation on the ability to manually replace many batteries. For low-energy IoT devices, energy scavenging from the environment is an attractive option.[5] Examples of energy scavenging techniques include light to electricity conversion (i.e. miniature solar cells); vibrational or other forms of energy gathering from motion or ambient sound; and scavenging ambient radio frequency energy from radio and TV stations.

Communications Infrastructure: The structure of the communications component of the IoT will be like the conventional Internet. But a key difference is that the communications backbone of the IoT needs to provide access to many more devices than the Internet does, and these devices are often in places where the conventional Internet is not accessible. As noted above, the energy consumption in many IoT devices is dominated by the energy in communications. Likewise, the energy consumption in the communications infrastructure is dominated by the parts of the infrastructure closest to the IoT devices.[6] This is because it is necessary to provide access nodes near all IoT devices. As the number of IoT devices increases, so does the number of access nodes and therefore the total energy consumption of the nodes. As data is aggregated further into the network (away from the IoT devices), the communications infrastructure is shared between many devices and efficiencies result from economies of scale.

As noted above, many IoT devices communicate by wireless. But wireless communications tend to be energy-hungry. One approach to reducing the energy consumption of the wireless infrastructure in the IoT is to share this infrastructure across a large number of IoT devices rather than place many access nodes near the devices. The emerging 5G mobile phone network incorporates energy-efficient standards for handling low-data-rate IoT traffic while sharing the same infrastructure with high-data-rate traffic. The extent to which the 5G mobile network is used as part of the IoT network infrastructure will have an impact on the energy consumption of the IoT.

Another difference between the conventional Internet and the future IoT is that in the Internet, most connected devices have access to most other devices. In the IoT this universal connectivity will not always be necessary or even desirable. For example, in a smart factory automated with many sensors and actuators, there is generally no need for external connectivity to each device. Security considerations would normally require that IoT devices in this kind of environment be completely disconnected from the outside world. In practice, then, the IoT will largely consist of numerous independent networks, some public, and some private. This will help to simplify the network and reduce energy consumption.

Data Centres: The energy consumption of the conventional Internet is dominated by data centres. Data centres participate in virtually every interaction on the Internet, from web searches to e-mails, video streaming and cloud computing. While the nature of the data in the IoT will be different, it is likely that data centres in the IoT will also dominate its energy consumption. One factor that will affect the energy consumption associated with data centres is the location of the data processing. Centralised or 'cloud' processing is efficient because the equipment is shared, but centralized processing requires more energy-consuming transmission infrastructure. Distributed processing, in which the data is processed in smaller processing units closer to the IoT devices could provide efficiency gains.[7] This is sometimes referred to as 'fog' processing.

Conclusion:

Many factors will influence how much energy the IoT will consume. With careful design, it will be possible to minimize energy consumption, but if the current predictions of the size and ubiquity of the IoT come to fruition, it is conceivable that by 2050, the IoT could consume between 1% and 5% of the world's electricity. The energy consumption of the IoT will be significant and may even exceed the energy consumption of the conventional Internet.

---

[1] M. Avgerinou, P. Bertoldi and L. Castellazzi, Trends in Data Centre Energy Consumption under the European Code of Conduct for Data Centre Energy Efficiency, Energies, 2017, 1470-1088.

[2] N. Jones, How to stop data centres from gobbling up the world's electricity, Nature (News), 13 Sept. 2018, 163-166.

[3] J. Morley, K. Widdicks, and M. Hazas, Digitalisation, energy and data demand: The impact of Internet traffic on overall and peak electricity consumption, Energy Research and Social Science, 2018, 128-137.

[4] C. Gray et al., "Power consumption of IoT access network technologies," IEEE ICC Workshop on Next Generation Green ICT, 2015, pp. 2818-2822.

[5] A. Adila et al., "Towards the self-powered internet of things (IoT) by energy harvesting: trends and technologies for green IoT," 2nd International Symposium on Small-scale Intelligent Manufacturing Systems, 2018, pp. 1-5.

[6] V. Tahiliani et al., "Green IoT systems: an energy efficient perspective," Conference on Contemporary Computing, 2018, pp. 1-8.

[7] F. Jalali et al., "Fog computing may help to save energy in cloud computing," IEEE Journal on Selected Areas in Communications, vol. 34, May 2016, pp. 1728-1739.