How energy-efficient is cloud computing?

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Researchers have found that, at high usage levels, the energy required to transport data in cloud computing can be larger than the amount of energy required to store the data. Image credit: Wikimedia Commons.

(PhysOrg.com) -- Conventionally, data storage and data processing are done at the user's own computer, using that computer's storage system and processor. An alternative to this method is cloud computing, which is Internet-based computing that enables users at home or office computers to transfer data to a remote data center for storage and processing. Cloud computing offers potential benefits – especially financial ones – to users, but in a new study, researchers have investigated a different aspect of cloud computing: how does its energy consumption compare with conventional computing?

In their study to be published in the *Proceedings of the IEEE,* Jayant Baliga and coauthors from the University of Melbourne in Victoria, Australia, have found that cloud computing is not always the greenest option. They investigated using cloud computing for three different services – storage, software, and processing – on public and private systems. (A public cloud is hosted on the Internet, and a private cloud is hosted within a company behind its firewall.) While previous studies of energy consumption in cloud computing have focused only on the energy consumed in the data center, the researchers found that transporting data between data centers and home computers can consume even larger amounts of energy than storing it.

"The most important conclusion in our analysis is that, when comparing the energy consumption of cloud-based services with that of a typical desktop PC, we must include the energy consumption required to transport the data from the user into the cloud resources and back," Rod Tucker, leader of the University of Melbourne research team, told *PhysOrg.com*. "This is particularly important if the cloud service is provided via the public Internet. Some papers that have claimed that cloud computing provides a 'greener' alternative to current desktop computing fail to include the energy consumption involved with transporting the data from the user into the cloud. In many cases, we may find that the data center used by the cloud-based services are located in another city, state or even country."

In general, not much attention has been paid to the energy consumption used in transmitting data, since cloud computing is more often praised for its other features. Some advantages of cloud computing are that it offers high-capacity storage and high-performance computing from any location with Internet access, while not requiring users to invest in new hardware or upgrade their software. Cloud computing systems can be free (such as Google Docs), or users may pay a yearly subscription fee or fee per resources used.

"Energy efficiency is crucial in two contexts," Tucker said. "Firstly, if the user device is a mobile device (phone, i-pad, PDA, etc.), then its battery lifetime is a key issue. Secondly, as the use of cloud services balloons, its energy consumption will likewise grow. The US Environmental Protection Agency estimated that in 2007 servers and data centers were responsible for about 0.5% of US greenhouse gas production. The greenhouse gas production that results from power consumption of data centers is expected to double between 2007 and 2020 if we just continue with business as usual. Without careful consideration of the power consumption of cloud services, their growing popularity will become a significant contributor to greenhouse gas production. Therefore, we need to develop technologies and strategies to address this issue before cloud services become more widespread."

When using the cloud for data storage (such as storing documents, photos, and videos using services such as Amazon Simple Storage), the researchers found that cloud computing can consume less power than conventional computing when the cloud service is used infrequently and at low intensities. This is because, at low usage levels, power consumption for storage dominates total power consumption, and power consumption for transport is minimal. But at medium and high usage levels, more energy is required to transport data, so that transport dominates total power consumption and greatly increases the overall energy consumed. Specifically, power for transport can be as low as 10% and 25% at low usage levels for private and public storage services, respectively, and nearly 60% and 90%, respectively, at high usage levels.

But overall, cloud storage services use less energy compared to cloud software and cloud processing. For cloud software services (such as Google Docs), the power consumption in transport is negligibly small as long as screen refresh rates are low (lower than 0.1 frames/sec, where 1 frame/sec means that 100% of the screen changes every second; a smaller percentage of the screen changing corresponds to a smaller screen refresh rate). However, for cloud software services, the biggest factor determining energy efficiency is the number of users per server, where more users corresponds to lower power consumption per user. In this case, public cloud computing, with its larger number of users, would benefit more than private cloud computing.

For cloud processing services (in which a server such as Amazon Elastic Compute Cloud processes large computational tasks only, and smaller tasks are processed on the user's computer), the researchers again found that the cloud alternative can use lower consumption only under certain conditions. The results showed that, for public cloud processing services, data transport consumed large amounts of energy compared to private cloud processing services, particularly at high usage levels. The reason is that the large number of router hops required on the public Internet greatly increases the energy consumption in transport, and private cloud processing requires significantly fewer routers. Still, the researchers found that, for both public and private clouds, a cloud processing service is more energy-efficient than older-generation PCs.

The results of the study mean different things for different users. As the researchers explain, home computer users can achieve significant energy savings by using low-end laptops for routine tasks and cloud processing services for computationally intensive tasks that are infrequent, instead of using a mid- or high-end PC. For corporations, it is less clear whether the energy consumption saved in transport with a private cloud compared to a public cloud offsets the private cloud's higher energy consumption. Private clouds that serve a relatively small number of users may not benefit from the same energy-saving techniques due to their smaller scale.

Overall, the researchers predict that the technology used in cloud computing – for example, data centers, routers, switches, etc. – will continue to become more energy-efficient. Most importantly, they recommend that one of the biggest areas of improvement is improving the energy efficiency of data transport, especially as cloud computing becomes more widespread.

"Many industry participants see the evolution toward mobility will intrinsically mean an evolution toward cloud-based services," Tucker said. "The reason is that mobile access devices will have limited processing and storage capacity (due to size and power constraints) and so the most convenient place to put the applications and data is in the cloud. The user device will contain little more than a browser when it is started up. Any application or data that it requires will be brought down from the cloud. When that application is finished, its data will be put back into the cloud and the application will be removed from the user device until it is again required. In this way, the user device is kept simple, energy-efficient and cheap."

More information: Jayant Baliga, et al. "Green Cloud Computing: Balancing Energy in Processing, Storage and Transport." *Proceedings of the IEEE*. To be published. DOI:10.1109/JPROC2010.2060451