

Oscillation

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Even today, computing technology continues to oscillate between localized and centralized data storage and processing.

When computers were first developed in the 1930s and 1940s (not counting Babbage's Difference Engine and other similar machines of the 19th Century), they tended to be large and single-program-at-a-time systems. We referred to "batch programming" in which only one computing job at a time consumed the entire machine. The machines got faster and one saw illustrations of large buildings theoretically filled with computer equipment that would run big computer programs in sequence. But then two strange things happened. The idea of making a machine share its computing power among multiple users ("time sharing") was invented in the early 1960s and machines began to get smaller and less expensive while delivering the same or even more computing capacity. Eventually, the centralized computing model was replaced by departmental computers and then by personal work stations, desk and laptop computers, and now, by smart phones and tablets. Concurrent with this evolution, computer networking evolved from the 1960s eventually to become the global Internet, linking many of these computing devices together. The personal computers were reconfigured and repurposed to fill warehouses full of racks of computers that could be shared by millions of users, returning us to the age of shared, centralized computing systems but with a major distributed component of memory and computing capacity.

Now a new trend is emerging: so-called *edge computing* with powerful computing capability positioned at the edges of the network, where personal devices also reside. The centralized facilities (warehouses) are still there but now we have distributed computing power once again at multiple levels in organizations and even residential settings. The Internet of Things will reinforce this trend. Billions of small, programmable devices will populate our offices, homes, automobiles and our persons. They will interact with and sometimes be protected by local computing capacity that shields the smaller devices from various kinds of attack or which serve as a kind of backup in case the Internet becomes unreachable. We see a related trend as content distribution services such as Akamai download and store content (e.g. music, videos and commonly referenced databases) to put them closer to the user's access to the Internet.

The result of all this is a persistent oscillation between localized computing and data storage and centralized storage and processing. While these oscillations take place, we also end up with concurrent centralized and distributed models operating across the Internet. Architecturally speaking, these phenomena introduce a strong demand for synchronization of content in a highly distributed environment. This is a nontrivial problem that calls for the deep thinking that led to Leslie Lamport's PAXOS family of protocols. The implications of this line of reasoning suggest that the oscillation between centralized and distributed computing will continue and that computing and storage will become normal adjuncts of almost all environments. In the extreme, we may find computing technologies such as the *memristor* becoming a normal part of many computing elements so that the classical Von Neumann architecture that separates computing from

memory blurs into a blended architecture that produces phenomena such as “instant on” that eliminate the need for “booting up” the operating system. Computation can continue where it was when power was turned off.

As newer computing technology emerges, perhaps in the form of bio-computing and storage systems, the ubiquity of computing and communication will become even more pronounced, leading the way towards the vision of Mark Weiser, who coined the term “ubiquitous computing” 30 years ago to describe his concept that computing and communications would blend into the background in such a way that we would not make much of a distinction between computers and everything else. Everything would have computational capacity and communication would be embedded into an omnipresent infrastructure. As we experience new modalities of interaction with computing via voice and gesture, this vision may rapidly become reality.

BIO

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