

Thick Clients for Personal Wireless Devices

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A thin-client approach to mobile computing pushes as many services as possible on a remote server. Technology trends indicate, however, that an easy route to improving thin-client functionality will be to add disk storage, RAM, and a more powerful CPU. Thus, thin clients will rapidly become multipurpose *thick clients*. With time, users may come to consider their mobile system as their primary general-purpose computing device, maintaining their most-used files on the mobile system and relying on their desktop systems primarily for larger displays, keyboards, and other nonmobile interfaces.

Personal digital assistants and wearable computers suffer from a tension between providing more functionality while maintaining a form factor appropriate to being carried on the user's body. Proponents of the thin-client approach observe that we will not, at least in the foreseeable future, be able to pack the same amount of technology into a pocket-sized device as in a contemporaneous machine-room server. Therefore, a thin client depends on a wireless network to provide connection to a remote server for resources, while the user-carried device provides only minimal functionality.

In its simplest form, a thin client consists of an input device and a display that receives updates from the wireless network. WAP phones offer a variation of this approach.



Thick clients will provide convenience, security, and the ability to operate while disconnected—and may even displace desktop PCs.

DISCONNECT INSURANCE

The idea of a thin client is not new—it was, and to some extent still is, used successfully for text and graphics terminals connected to a central server by wired networks. Wireline terminals and the wireless personal devices being developed today, however, differ in two significant ways: Wireless devices have limited power, and they must operate with the expectation of network connectivity loss.

The network connectivity issue carries broad implications. In many places, providing full-speed wireless Internet coverage will remain financially infeasible for the foreseeable future. For example, providing wireless connectivity in a rural community located in a harsh climate or in a mountainous area where the roads wind through a tunnel system presents a number of challenges.

Another common example of wireless disconnect occurs during airplane flights—especially during taxi, take-off, and landing. While providing connectivity during these times is feasible,

regulations prohibit doing so.

In its most strict form, a thin client simply does not operate during network outages. However, with the addition of local storage to cache the user's current data and a local processor to manipulate it without the network, the outage could be transparent as long as the user doesn't need to access data located outside the local cache.

The more data the thin client caches and the more processing power it has, the greater chance that the user can continue editing a presentation or playing a video game uninterrupted. However,

when does a thin client become a thick client? When is it more profitable to think of and manufacture a mobile device as a separate entity rather than as a network interface?

TRACKING THE TRENDS

Figure 1 shows the progression of laptop computer technology during the past decade. The graphs depict increases in performance as multiples of the state of technology in 1990. Given the exponential nature of the improvements, the y-axis is on a logarithmic scale. A high-end machine in 1990, the base value of 1 in the graph, consisted of a 16-MHz 80386 with 8 Mbytes of RAM and 40 Mbytes of hard-drive space. The chart compares

- processor performance in terms of Intel's iCOMP index (<http://www.cpuscorecard.com>);
- RAM and disk storage by size in megabytes;
- wireless networks in maximum nominal bits per second of data transfer; and

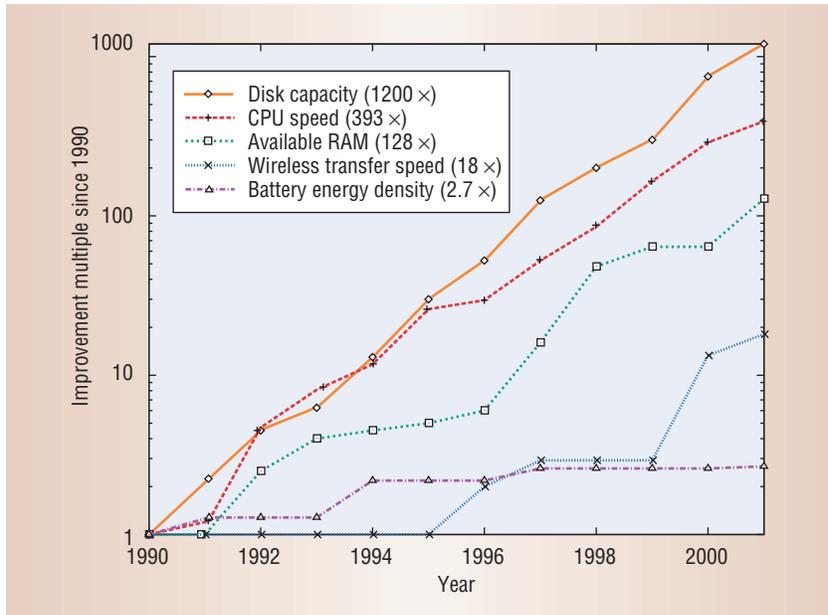


Figure 1. Laptop technology improvements during the past decade. The logarithmic scale shows multiples of the technology's improvement since 1990.

Further Reading

- Recent overviews of the issues facing mobile computing:
M. Satyanarayanan, "Pervasive Computing: Vision and Challenges," *IEEE Personal Comm.*, Aug. 2001, pp. 10-17.
T. Starner, "The Challenges of Wearable Computing," *IEEE Micro*, July 2001, pp. 44-67.
- Methods of operating with highly variable network connectivity:
J. Kistler and M. Satyanarayanan, "Disconnected Operation in the Coda File System," *ACM Trans. Computer Systems*, Feb. 1992, pp. 3-25.
- Details on the future of increasing disk densities:
D. Thompson and J. Best, "The Future of Magnetic Data Storage Technology," *IBM J. Research and Development*, May 2000, pp. 311-319.
- Discussion of the energy constraints on nodes in wireless networks:
J-H. Chang and L. Tassiulas, "Energy Conserving Routing in Wireless Ad Hoc Networks," *Proc. Infocom*, vol. 1, 2000, pp. 22-31.

- battery energy density in Joules stored per kilogram (J/kg) as determined by the type of technology used—nickel cadmium, nickel metal hydride, or lithium ion—and the progress these technologies have made.

In general, if repackaged in a personal device worn on the body, the laptop technology represented in the

graphs could be used while standing on a street corner in a major US city. Thus, while 15-pound "luggable" computers with more advanced technology may have been available during the years shown, these graphs only reflect statistics for laptop computers of approximately seven pounds or less. Even then, high-power displays and their batteries account for much of these machines' weight. This is a sig-

nificant consideration because laptop size limits the amount of heat the device can dissipate—a major constraint in modern laptops.

Leading indicators

The typical specifications listed in the advertisements for the highest-end laptops in each year's December issue of popular computing magazines were used to generate these graphs. The wireless connectivity graph represents the commercial, license-free, citywide networks available in the US. Until the mid-1990s, wireless connectivity consisted of modem access over analog cellular phones, which was unreliable while moving. Although the specific technology examined when creating the graph is often inappropriate for personal digital assistants and wearables—for which battery life and heat dissipation are limiting issues—the graphs do demonstrate trends that should apply to such devices in the future.

In examining the graphs, the most striking trend is the 1,200-fold increase in disk space that the survey demonstrates. Since 1993, disk capacity has continued to increase significantly faster than the technologies that Moore's law governs, as reflected in the CPU and RAM graphs. At the current rate, disk density doubles every 12 months. According to IBM data (see Thompson and Best in the "Further Reading" sidebar), this rate can be sustained for at least several more generations. Thus, in five years, a mobile device may provide more than a terabyte of disk storage. Users will be able to store not only documents on these devices, but also an entire video collection.

Trailing indicators

Wireless transfer rates and battery energy density are the laggard trends. In particular, energy density has only increased by approximately threefold in the past decade. This is particularly troublesome because energy density affects both mobile device size and exploitation of the other trends.

WIRELESS CONSTRAINTS

In addition to their slow improvement, citywide wireless services have other constraints. The hardware available at deployment limits the wireless network's coverage and speed. Further, companies that do not manufacture mobile devices often control the networks. Thus, a device designer cannot depend on the continued increase in data rates or even the availability of a wireless network, as evidenced by the recent discontinuation of the Metricom 128-Kbps service.

While increases in transistor and disk density and lower operating voltages continue to improve available RAM, disk, and CPU functionality per Joule of energy used, the inverse square power law still constrains wireless networks.

In practice, the amount of power needed to transfer data can increase with the fourth power of the distance to the network node. Wireless service providers can combat this problem by increasing the number of wireless transponders in a given area, but average connection distance decreases slowly with the increased number of transponders—assuming an even distribution of service and service need in an area.

To improve thin clients, mobile designers should concentrate on the caching that the rapid increase in disk capacity and RAM can provide. In addition, to help alleviate power use by wireless networks, designers can use increased processor capabilities and RAM to compress the data to be transferred.

Once transferred, powerful processors can use local resources to manipulate the data. However, these tools—disk capacity, RAM, and CPU—are precisely the characteristics that normally define a *thick* client.

WEARABLE COMPUTERS AS MOBILE THICK CLIENTS

At the opposite extreme from a mobile thin client is the wearable computer that I use in place of a desktop

computer. With such a system, users maintain and manipulate the primary copies of their files on the wearable computer instead of on a server. Larger desktop machines serve primarily as computation workhorses and as portals to high-speed networks—similar to how mainframes are used in conjunction with personal computers today. Significant benefits of this on-body approach include the user's sense of data ownership, *continual* access to the most up-to-date data from the user's personal perspective, and the data's physical security.

Device size presents a potential objection to a mobile, general-purpose system with large storage capacity. In actuality, given the trends described, the main size constraint will be the human interface. For example, the keys on a keyboard can only be made so small before affecting typing speeds, while displays—even head-mounted ones—become unusable if their pixels shrink beyond the resolution of the eye. Given these interface constraints and the continuing issue of providing power to a mobile device, designers should exploit technology trends to provide a wide variety of devices that allow the consumer to trade size for functionality, as is the case with the current laptop market.

The effort to provide computational support while mobile will encounter many challenges in the years to come. Given past technology trends, mobile thick clients will play an increasingly important role in the development of the mobile marketplace, perhaps replacing the desktop as the predominant location for a user's personal files. Debuting in 2002, *Pervasive Computing*, the IEEE Computer Society's newest magazine, will discuss mobile computing's trends and challenges. ■

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