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Response to *the Collapsed LAN* *

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In a recent paper in this publication, Professors Wilkes and Hopper proposed a shift in architecture they referred to as the *collapsed LAN* [6]. One of its basic concepts is to separate the display, keyboard and mouse (they referred to this as the *terminal*, we will call it the *head*), from the CPU and storage chassis by a dedicated fiber-optic cable. This allows the chassis to reside in a machine room, where it can be cared for properly and interconnected with other hosts over substantially shorter distances than are common in a local area network (LAN).

We thank them for raising important fundamental issues in the design space of computer systems, and take this opportunity to augment the discussion. We would like to make readers aware of some additional examples of similar architectures, as well as point out some research on other points in the physical design space of CPU chassis and display heads.

One successful example is the Symbolics 3600 series of Lisp machines and its successors, which were popular with AI researchers in mid-1980s [4]. A large, bitmapped display, custom keyboard and mouse served as the user's interface to the machine. However, the machine's size and power and cooling requirements necessitated it being in a well-cooled, raised-floor computer room. Thus, a special cable was required to connect the chassis in the machine to the head in the researcher's office, often several floors away. The video signal was generated on the display driver board in the CPU chassis, and piped as an analog signal to the display head. Initially the cable was coax for video with additional lines for peripherals, but a third-party fiber optic cable was available. The Texas Instruments Explorer series of Lisp machines utilized a similar physical configuration.

X terminals, which require access to remote servers to function effectively, and provide a lightweight, low-maintenance head in the office, arguably are an example of a closely related architecture. The X terminals communicate with the compute servers via a local-area network and the X network protocol. The video signal is generated independently at the X terminal.

A related point in the design space is one in which only the storage elements are connected to the host via a network such as Fibre Channel. The National Storage Industry Consortium hosts a working group on network-attached storage devices [7]. This provides some advantages similar to those proposed for the collapsed LAN, such as centralized physical control of important resources.

Recently, research has been done on architectures centering around network-attached peripherals which would allow physical configurations separating the display head from the CPU and peripherals [5]. These systems, which replace the bus with a network, are predicated on the observation that LANs scale better than buses in aggregate bandwidth and number of hosts or devices, and are on a faster technology improvement curve. Cambridge's own Desk Area Network [2], MIT's ViewStation [3], and ISI's Netstation [1] are examples. Using such a system, a display and keyboard can communicate via a shared network to the CPU chassis, eliminating the expense of the dedicated cable at the cost of sharing the network. The network protocols tend to be lower-level than X. The video signal is generated at the display hardware.

Ultimately, the "correct" physical design and placement of the components that make up a computer system is a complex combination of work load, physical constraints and technology. Assumptions

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about bandwidth and latency requirements of applications and the future of technology (especially, in this case, the continued evolution of high-speed LANs and their fiber optic interfaces) affect the proper choices for given environments. The exploration of these issues is an exciting area in computer architecture, and Prof. Wilkes and Hopper's article exposes one of the design dimensions.

Space precludes exploring all the issues in centering an I/O architecture around a network interface. Interested readers are invited to send the authors email to continue the discussion of the design space.

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