Technology Trends in Network Technology

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1. Network Latency

Between 1989 and 1994 network RPC latency improved by less than a factor of three, from 2.66 ms [Schroeder and Burrows, 1990] to about 1.00 ms, a speedup of about 20% per year. However, a number of research efforts have demonstrated extremely low network latency using protocols somewhat more restrictive than those of RPC. Thekkath, for example, demonstrated a restricted RPC protocol with 72 µs round-trip latency on 155 Mbit/s ATM [Thekkath and Levy, 1993], and Martin and von Eicken have measured 29 µs and 52 µs round trip times for active message implementations using FDDI and ATM, respectively [Martin, 1994, von Eicken et al., 1995]. If any of these simplified protocols could be used as a fast path for file system communication, order of magnitude improvements in network latencies may be possible.

Whether or not research efforts provide new protocols, network latencies are significantly smaller than disk latencies, and they seem likely to improve more quickly in the future. As a result, networks will provide faster access to small data items than will disk.

2. Network Bandwidth

Over the past 15 years, the aggregate network bandwidth available to a 32-node cluster of high-end, desktop workstations has increased by a factor of 256, from a 10 Mbit/s shared Ethernet in the early 1980's to a 2,560 Mbit/s switched, Myrinet [Boden et al., 1995] network in which half of the workstations can each send at 160 Mbit/s while half receive at the same rate. This improvement represents an increase of about 45% per year over this period. This improvement in network speed has come from two sources, faster network links to each machine, and better topologies to increase the aggregate bandwidth above the per-link bandwidth. The per-link bandwidth has increased by a factor of 16 over this period, at about 20% per year. The other factor of 16 comes from the move from the bus-based Ethernet to switch-based topologies [Schroeder et al., 1991] such as ATM [ATM Forum, 1993], Myrinet, and switched Ethernet.

Although the one-time move from bus-based topologies to switch-based topologies contributed significantly to the improvement in network bandwidths over the last decade, large improvements in network speed are likely to continue because it is easier to increase the speed of switched network links than bus-based network links. First, many switched networks allow individual links to be upgraded independently; in the past, a network's speed could only be increased if all of the machines in a system were simultaneously upgraded. Second, electrical signalling is easier on these point-to-point networks; the bandwidth of the Myrinet network, for instance, is limited by the workstation's I/O bus bandwidth rather than the 640 Mbit/s physical link bandwidth [Martin, 1995].

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