Trends in Memory Technology

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1. Memory Bandwidth

Improvements to DRAM architectures — including wider memories, memory interleaving, and efficient access modes [Bursky, 1992, Jones, 1992, Prince et al., 1992, Hart, 1992, Bondurant, 1992] — allow memory bandwidths to improve quickly. Table 1 summarizes the memory-to-memory copy bandwidths of machines available in 1989 compared to machines measured in late 1994 and suggests that memory bandwidths are increasing at 40% per year or better for each product line. In absolute terms, memory speeds are much faster than disk speeds, and the relatively high rate of memory speed improvements suggest this gap will remain large.

2. Memory Capacity

The capacity of memory chips increases at about 60% per year due to improvements in technology that quadruple the amount of memory that can fit on a chip every three years [Hennessy and Patterson, 1996]. As Figure 1 indicates, before 1992, memory prices reflected this trend, falling at over 100% per year during that time. During the last three years, however, the cost per megabyte of memory has been flat. It is not yet clear whether this drastically reduced rate of improvement in cost is a long-term effect or a temporary blip. Over the full seven-year period indi-

	1989		1994		Five-year Average Rate of Increase
Manufacturer	**Machine**	**Bcopy Bandwidth**	**Machine**	**Bcopy Bandwidth**	
SUN	SPARCStation 1	5.6 MB/s	SPARCServer 20 Model 6	27.9 MB/s	38%/year
Hewlett-Packard	9000-835CHX	6.2 MB/s	715/80	32.1 MB/s	39%/year
IBM	RT-APC	5.9 MB/s	6000/370	67.2 MB/s	63%/year
Digital Equipment	DS3100	5.1 MB/s	3000/400	43.8 MB/s	54%/year

TABLE 1.**Memory bandwidth for 1989 and 1994 machines.** The 1989 values were measured by Ousterhout [Ousterhout, 1990]. The 1994 values are for large, 10 MB transfers to reduce cache effects. The rate of increase is the change for each manufacturer for the products listed computed over five years. Note that these rates would differ somewhat if different products in each vendor's line were chosen.

cated in the figure, prices fell by an average of about 45% per year, but the most recent trends suggest that this may be an optimistic estimate for memory-size improvement rates. In any event, memory capacity seems likely to grow more slowly than disk capacity in the future.

References

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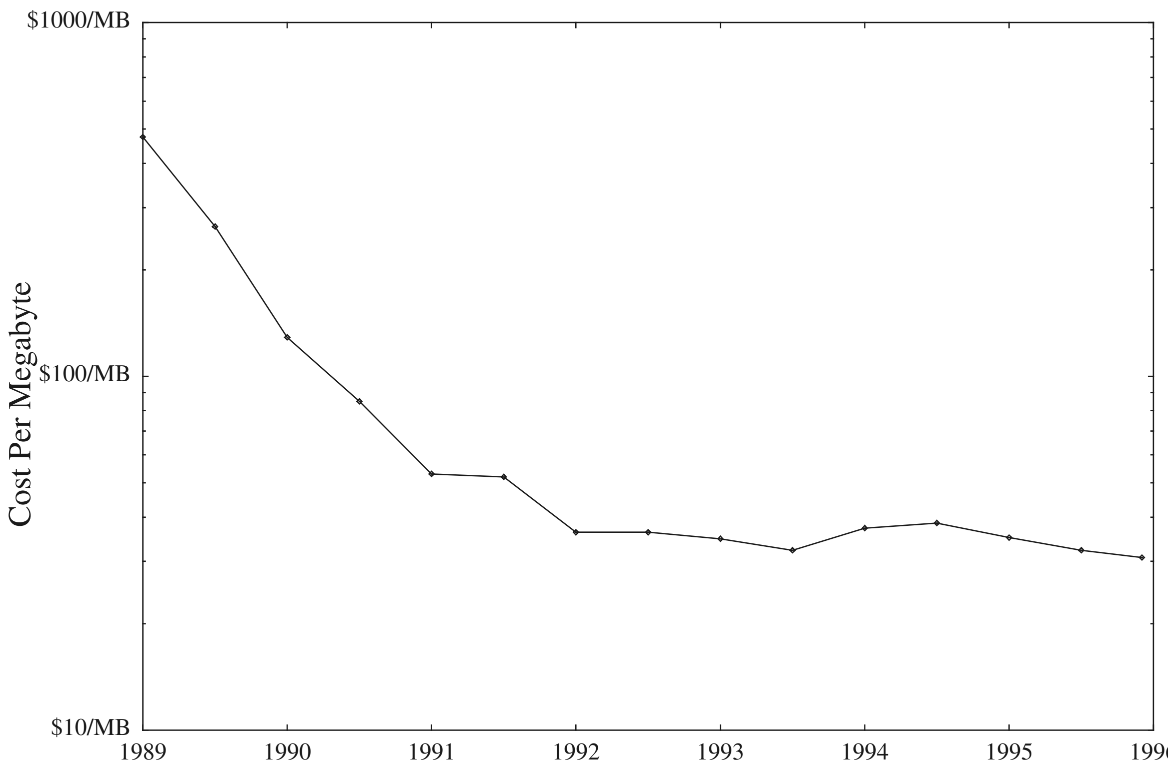

FIGURE 1. **DRAM price per megabyte.** Each point indicates the cost per megabyte of DRAM memory based on advertisements from *Byte* magazine. All prices reflect memory purchased in 9-bit-wide SIMM form with access times of 80 ns or better. To provide the best price for each data point, points before July of 1991 are the prices for 1MB SIMMs, and points from July of 1991 and later are one quarter of the prices of 4 MB SIMMs. Note the log scale for the y axis.