

disadvantages as well. Some, like the higher cost in comparison with conventional systems, are inevitable. Others were not so obvious to the designers.

Performance

Tandem was justifiably proud of the near-linear scaling of performance when hardware was added. Horst and Chou (1985), which refers to a later system, the TXP, shows how a FOX cluster can scale linearly from 2 to 32 processors.

Bartlett (1982) shows the downside: the performance of the message system limited the speed even of small systems. A single message with no attached data takes over 2 ms to transmit, and messages with 2,000 bytes of data in each direction take between 4.6 ms (same CPU) and 7.0 ms (different CPUs). This is the overhead for a single I/O operation, and even in its day it was slow. The delay between sequential I/O requests to a disk file was long enough that they would not occur until the data had passed the disk head, meaning that only one request could be satisfied per disk revolution. A program that sequentially reads 2 kB from disk and processes it (for example, the equivalent of *grep*) would get a throughput of only 120 kB/s. Smaller I/O sizes, such as 512 bytes, could limit the throughput to floppy disk speeds.

Hardware Limitations

As the name “Tandem/16” suggests, the designers had a 16-bit mindset. That is fairly typical for the mid-1970s, but the writing was already on the wall that “real” computers had a 32-bit word. In the course of time, successor machines addressed a number of the issues. In 1981, Tandem introduced the *NonStop II* system with an upward-compatible instruction set and fewer hardware limitations. Over the next 10 years, a number of compatible but faster machines were introduced. None were extremely fast, but they were fast enough for online transaction processing. In addition, the operating system was rewritten to address the more immediate problems, and over the course of time additional improvements were made. The changes included:

- Introduction of a 31-bit address mode to give user processes “unlimited” memory space. This mode used byte addresses, but it didn’t remove the limitations on stack size and code spanning the 32 kB boundary, since the old instruction formats remained.
- Increase in the number of hardware virtual memory maps. The T/16 had only four, for the code and data spaces. The TNS/II, as it was called, had a total of 16 memory maps, which meant that the processor could directly address up to 2 MB without involving the memory manager. One of these maps was used as a kind of translation lookaside buffer to handle the 31-bit extended addresses.
- Guardian II, the new version of Guardian that came with the TNS/II, also featured system library and user library spaces, which increased the total space available to processes to 384 kB. Still later, the number of library spaces was increased from 2 (system and user)