Synchronization

This approach proves very reliable, and it can deliver reliability superior to that of a pure lockstep approach. In some classes of program error, notably race conditions, a process that is running in lock-step will run into exactly the same program error and crash as well. A more loosely coupled approach can often avoid the exact same situation and continue functioning.

A couple of issues are not immediately obvious:

- Checkpointing is CPU-intensive. How often should a process checkpoint? What data should be checkpointed? This decision is left to the programmer. If he does it wrong and forgets to checkpoint important data, or does it at the wrong time, the memory image in the backup process will be inconsistent, and it may malfunction.
- If the primary process performs externally visible actions, such as I/O, after performing a checkpoint but before failing, the backup process will repeat them after takeover. This could result in data corruption.

In practice, the issue of incorrect checkpointing has not proved to be a problem, but duplicate I/O most certainly is a problem. The system solves this problem by associating a sequence number called a *sync ID* with each I/O request. The I/O process keeps track of the requests, and if it receives a duplicate request, it simply returns the completion status of the first call to the request.

Networking: EXPAND and FOX

The message system of the T/16 is effectively a self-contained network. That puts Guardian in a good position to provide wide-area networking by effectively extending the message system to the whole world. The implementation is called *EXPAND*.

From a programmer's point of view, EXPAND is almost completely seamless. Up to 255 systems can be connected.

System names

Each system has a name starting with a backslash, such as `\ESSG` or `\FOXII`, along with a node number. The node numbers are much less obvious than modern IP addresses: from the programmer's perspective, they are necessary almost only for encoding file names, which we'll see later.

EXPAND is an extension of the message system, so most of the details are hidden from the programmer. The only issues are the difference in speed and access requirements.

FOX

Considering purely practical constraints, it is difficult to build a system with more than 16 CPUs; in particular, hardware constraints limit the length of the interprocessor bus to a few meters,