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Controlling Amtrak Trains in the Northeast Corridor

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In the early 1990s, my company, The Sombers Group, Inc., was awarded a USD one million dollar contract by Amtrak to develop a system to control its trains along the Northeast Corridor from Washington, D.C. to Boston. The contract came about because of problems that Amtrak was having with its Tandem computer-based control systems. The systems had been installed a couple of years earlier by another company, but they never functioned properly.

The systems involved two Tandem computers – one in Penn Station, Philadelphia, to control train traffic from Washington, D.C. to Hartford, Connecticut, and one in Boston for trains traveling from Harford to Boston. We had been doing other work for Amtrak and were asked if we could get the Boston system working.

I sent Paul Siegel, one of my top technicians, to Boston to take a look. Surprisingly, Paul had the system working properly within a month. He became a local hero at Amtrak.

With that success, Amtrak asked us to straighten out its main system in Philadelphia. Amtrak estimated that it would require just a few software changes and gave us a fixed price contract based on their estimate. However, when we got into the system, we realized that it would pretty much have to be rewritten. By the time we were finished a year later, Amtrak had poured over a million dollars into the new system.

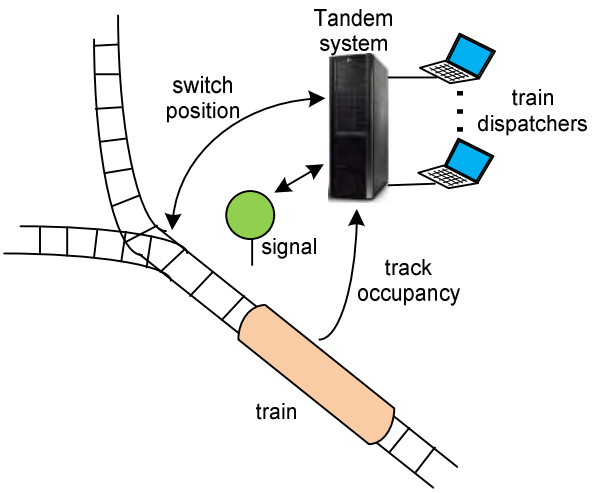
The Tandem Train Control System

The Tandem train control system was driven by a database that contained the Amtrak track model for the entire Northeast Corridor. The track model contained every track segment, switch, and signal light that existed in this area.

The track model was kept up-to-date by signals from the field. Trains were located via track occupancy detectors. These were nothing more than relays that were thrown when a train short-circuited the two rails of track. Signal lights indicated their current state to the Tandem (stop, go, caution), and switches indicated their current position.

The Tandem system could control the position of switches and the state of signal lights to move trains along their intended paths.

Trains were controlled by Amtrak schedules. When a new train was due to leave its originating station, train controllers (dispatchers) using touch-screen Unix terminals connected to the Tandem system determined the best route for the train to take. The system then controlled switches and signal lights to allow the train to follow that path. It there was a conflict along the route, the Tandem system would stop the train via signal lights until the conflict was resolved.



The Role of Middleware

NetWeave middleware was used extensively in the control system to connect the Tandem system with other systems. NetWeave provided several middleware services including Remote Procedure Calls, data replication, and store-and-forward messaging.

With RPCs, two computers established a communication link between themselves, letting one computer trigger a procedure or application on the other computer. RPCs were used to order computers along the track to throw switches into the correct positions and to control the signal lights.

Data replication was used to keep the dispatcher terminals updated with the current track model. Train dispatchers used touch-screen Unix terminals connected to the Tandem system to monitor and control traffic. The track model for the portion of the track a dispatcher was managing was displayed on his terminal. Whenever there was a change in the track model (a train moved, a switch was thrown, a signal light was changed), the new track model was replicated to the dispatcher's terminal. Thus, he always had an up-to-date view of his portion of the track model.

When a train was about to enter a dispatcher's assigned track area (either a new train or a train from another area), his workstation would suggest routes for the train to take. When the dispatcher selected a route, the routing data was forwarded to the central Tandem database, from where it was replicated to other dispatchers' workstations.

A train dispatcher managed his track section by entering commands via his terminal to throw switches and to change signal lights. These commands were sent to the Tandem system, which would then issue RPCs for the requested actions. The changes in switch positions or signal light states were returned to the Tandem system, which updated its track model. The track model changes were then replicated to the dispatcher terminals. This gave the dispatcher positive feedback that his command had been executed.

Amtrak coordinated with other railroads via store-and-forward messaging. If a train were to enter the Amtrak system from another railroad, or if an Amtrak train were to transit to another railroad, the two railroads coordinated the move via store-and-forward messaging.

Availability

The Amtrak specifications called for a system availability of 0.9998, including the Tandem system, the dispatcher Unix workstations, and the network connecting the Tandem to the field devices. Our first calculations showed an availability of 0.9995, which Amtrak would not accept.

The problem was in the Tandem system. It was an eight-CPU system, and the assumption was that it would survive any single CPU failure but that a second CPU failure would bring it down. There were 28 ways two CPUs can fail in an eight-CPU system.

The solution was to reduce the number of failure modes. We reorganized the software processes so that there were only twelve ways a pair of CPU failures would take down the system. This brought us well into the availability specification, and the system was accepted by Amtrak.

The Backup System

There was no backup system for the Tandem train control systems. Rather, if the system failed, the train dispatchers would move to the basement where a hard-wired track model was located on a large board. Lights on the board indicated where trains were. The status of signals and switches was also shown on the board. The train dispatchers could control trains by throwing switches and changing signal states via controls on the board.

A Surprise Ending

After several years of service, for reasons unknown to the author, Amtrak decided to replace its Tandem systems with networks of PCs. So far as I was concerned, this akin to a farmer replacing his tractor with a thousand chickens.

The project was a management nightmare. There were dozens of PCs involved, and they all had to work together flawlessly. It took almost two years to get the PC network to function properly. But it finally did, and the Tandem systems were retired. Sob!