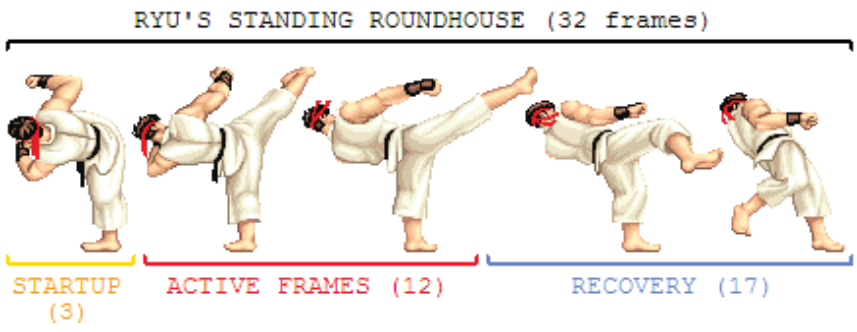

FIGURE 4: On most broadband connections, GGPO can mask the lag in the start-up phase of a Street Fighter move.

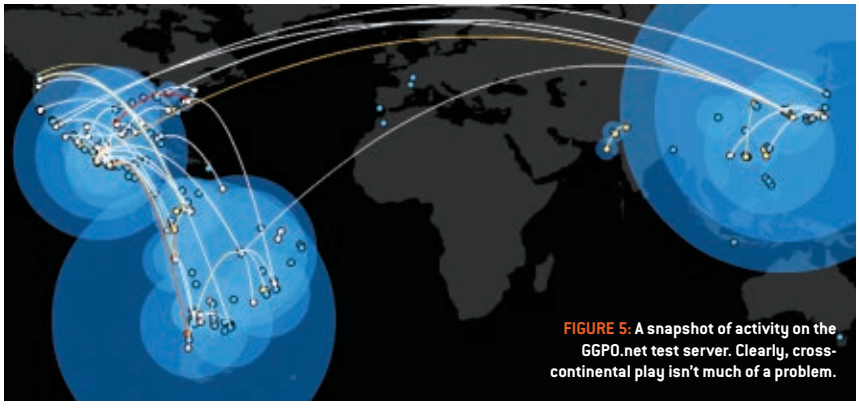

FIGURE 5: A snapshot of activity on the GGPO.net test server. Clearly, cross-continental play isn't much of a problem.

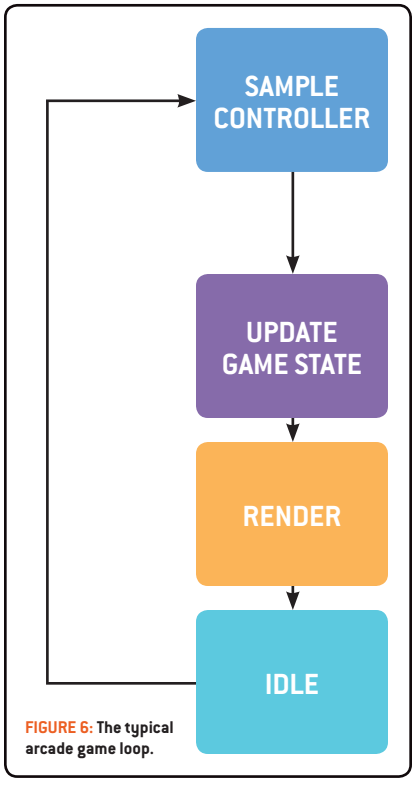

FIGURE 6: The typical arcade game loop.

that the player actually did throw the fireball. This makes the timing and experience of dealing with a fireball online identical to the experience offline, which is important, as dealing with fireballs is a major part of STREET FIGHTER!

Similarly, opponents usually cannot change the arc of their jumps after initiating them, so dealing with your opponent descending from a jump, perhaps with a well-placed Dragon Punch, is identical both online and offline. So if everything appears to be correct all the time, where'd the latency go?

The latency is hidden in the window between when your opponent initiates an action and your simulation realizes that an action was performed. The time lost in that window is effectively skipped to your simulation. For example, suppose both you and your opponent are playing a game of STREET FIGHTER on a network that takes 60ms to send a packet from one console to the next. When your opponent executes a move, his simulation will process the controller inputs immediately. To him, the move comes out right away, since local inputs are sent to the simulation immediately and are always correct. Your simulation, however, will not notice that your opponent performed a move for another 60ms, when a packet arrives from the network carrying that input. When it does, GGPO will instruct the game to rewind 60ms, correct your opponent's input, and fast-forward the game simulation 60ms back to the current time. As a result, on your console you will not see the first 60ms of animation of whatever your opponent did. It is as if the move began 60ms into the animation, from your perspective.

This is not ideal, but the alternative is to delay the entire simulation by 60ms, including local inputs. In practice, losing those 60ms of animation usually results in a greatly preferable user experience. This is partially due to the greatly increased responsiveness of local actions, but is also because most of the time those 60ms just don't matter that much. To illustrate this, let's look at a specific example.

Most attacks in STREET FIGHTER have three phases: start-up, execution, and recovery (see **Figure 4**). The start-up of a move is how long a move takes to become active after the user presses the button. While there is usually some animation state associated with the start-up of a move, the move isn't actually doing any damage yet. The serious business happens in the execution window; if the opponent overlaps your move's active region at any time during the execution window, the game simulation will register it as a hit. A hit causes the simulation to start new animations, play audio, subtract some life from your opponent, and lots of other effects. It's a big deal as far as simulation state is concerned. Recovery is simply the duration after a move executes before you can perform another one.

These numbers are usually measured in frames, and the first thing competitive STREET FIGHTER players do when a new game comes out is to mine the frame data for every move in the game to begin researching tactics. If we look at the frame data for one of the most beloved and fastest STREET FIGHTER games on the market, SUPER STREET FIGHTER II TURBO (http://nki.combovideos.com/flame.html), we see that a vast majority of the moves have a start-up of at least four frames (or 66ms). That's incredibly important to us, because it means that on a 120ms ping connection, it's possible to resolve almost every rollback before the execution of a move, which means that the visual and audio glitches that result from incorrect predictions are almost always limited to the animation of the start-up of a move, not the result of hitting your opponent.

Modern broadband connections from Los Angeles to New York typically have a faster ping than 120ms. In fact, anecdotal evidence