Time synchronization improvements in T2K

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T2K (Tokai to Kamioka) is a long-baseline neutrino beam experiment under way in Japan. Recently there has been increased interest in measuring neutrino time-of-flight (TOF) over long distances using neutrinos of known momentum. TOF measurements may allow us to set an upper limit on neutrino mass, assuming neutrino velocity is interpreted in the context of the relativistic mass-energy relation, by a method completely independent of other techniques used to date. T2K generates and samples a neutrino beam, with well-defined momentum and time structure, at the J-PARC proton accelerator in Tokai, Ibaraki prefecture, on the Pacific coast of Japan. The beam travels through the earth to the Super-Kamiokande underground neutrino detector, 295 km away, near Kamioka, Gifu prefecture, in western Japan. Measurement of TOF over a baseline of 295 km requires relative timing between sites much better than O(50 ns), the specification for the synchronization system now in use, which was adequate for our original experimental goals. We will describe the upgraded hardware and methods used to to bring T2K time synchronization accuracy down to the nanosecond scale, including detailed timing calibrations of proton, muon and neutrino beam detectors at the near and far sites. The resulting improvements form the basis for an absolute neutrino TOF analysis within the T2K experiment.