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A High Speed Network for Remote Observing from Caltech with the Keck Telescope

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Abstract. We are setting up a high speed (DS3) ATM network running from the dome of the 10-meter Keck Telescope on the summit of Mauna Kea in Hawaii to the Caltech campus in Pasadena, California. This network will be used to support remote observing, remote diagnostics of problems, remote software development, and other related tasks. We discuss the motivation for this effort, the network architecture, and the current status of this project.

1. Introduction

The W. M. Keck Observatory, located at an altitude of 13,600 feet on the summit of Mauna Kea on the Big Island of Hawaii, consists of twin 10–meter telescopes intended for astronomical observations at optical and infrared wavelengths. The first Keck Telescope has been in routine operation for more than a year. It is the largest astronomical telescope in the world for use at these wavelengths. The second Keck Telescope is expected to become operational in mid-1996.

The high altitude of this site causes problems. In spite of the requirement that all astronomers spend a night at Hale Pohaku (altitude ≈9000 feet) for acclimatization before proceeding to the summit for a night of observing, about 15% of the people who do not observe often at Mauna Kea become sufficiently ill during the course of a 3 night run that they have to leave the summit for at least 12 hours. Approximately 75% of the people coming to the summit to observe for a full night experience some discomfort such as a mild headache, and almost all experience some loss of judgment, irritability, etc.

There are a number of other compelling reasons that lead one toward the concept of remote observing. The scheduling of observing time on the Keck Telescope is done on the basis of proposals submitted by scientists from the member institutions and there is a large over-subscription ratio. This results in observing runs that are short, typically 2 nights. A typical project involves several people, and while the number of people who travel to Hawaii for a given night varies widely from project to project, the average is 2 to 3 people. This means substantial sums are spent by the member institutions on travel and related expenses. It also means that with these short runs the salary cost for "wasted time" during travel or while acclimatizing to the altitude is very large.

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In addition to these operational advantages, there are strong scientific advantages to remote observing as well. With remote observing, every member of a large collaboration can participate in obtaining the data. It will be possible for one part of the team to concentrate on obtaining the observations, another person can be analyzing the scientific results from the last integration, another can be checking the instrumental performance to make sure everything is working correctly (particularly the detector), and a fourth group of people can be checking the literature or catalogs of objects as necessary to prepare for the next set of observations. The inclusion of students in the observing session becomes much easier and more routine when no travel is required, they don't need to miss classes, etc.

Astronomical images are large. The optical instruments currently in use at the Keck Telescope have frames that are 8 megabytes in size, and soon these arrays will become 3 times larger. Integration times depend on the scientific program, and range from less than a second to an hour. The quality of ground based optical and infrared astronomy observations is very sensitive to weather conditions, including clouds and atmospheric turbulence. Hence, although observing sessions may be planned in detail in advance, careful quick-look on-the-spot analysis of each image is important in defining what to do next, how long the next exposure should be, whether to switch to brighter objects due to poor sky conditions, how to modify the program to cope with unexpected failures of non-critical telescope or instrument components, etc.

Remote diagnosis of problems becomes feasible once a high speed network exists. The teams that built the instruments for the Keck Telescope are located at Caltech or a campus of the University of California. These engineers cannot rush off to Hawaii with no notice when there is a problem that the staff in Hawaii feel they cannot resolve. With a high speed network, the engineers in California can test the operation of the equipment remotely, see the results of these tests essentially instantaneously, and diagnose the problem quickly.

Remote software development and debugging will also become feasible again with such a high speed network. During the early stages of construction of the instruments, some efforts along these lines were done across the Internet link between California and the Keck summit, but over the past 3 years that link has become so saturated with traffic and so slow as to be completely useless. Again both travel and time are saved, and effective help from highly skilled and experienced people in California can be obtained quickly when necessary.

2. The ACTS Satellite and the Plan for the High Speed Network

Throughout the design process of the hardware and software for the Keck Telescope the possibility of implementing remote observing from Waimea, the location of the Keck headquarters in Hawaii, (and eventually from California once suitable networks became affordable) was kept in mind. The instruments, their motors, and detectors are run through workstations that are located in the control room of the Keck Telescope dome. All the instrument and telescope control software was written using X Window System displays. It is not necessary during normal night time operation to go out to the instrument on the telescope to make any adjustments or changes.

The main deterrent to the implementation of remote observing has always been the problem of obtaining an affordable and reliable connection with adequate bandwidth. NASA's Advanced Communications Technology Satellite was built as a prototype system to explore new modes of high speed transmission for digital data. It provides this capability at rates reaching up to OC-12 via advanced on-board switching and multiple dynamically hopping spot beam antennas for selected areas of the United States, including Pasadena and Hawaii, although the steerable antenna used to reach sites not in the continental U.S. is only capable of OC-3 speed. The 20–30 GHz frequency band, not previously used by a communication satellite, is utilized, with extensive rain fade compensation.

ACTS was launched in September, 1993. In response to an announcement of opportunity issued by NASA, a proposal was submitted by JPL for the use of ACTS as part of a network for the remote control of the Keck Telescope and its instruments, as well as to work on other issues closely related to remote observing. This proposal was chosen for funding and allocated several nights per week of ACTS satellite time for an 18 month period.

BBN has designed and built the high data rate (HDR) ground stations that provide a gateway at these high data rates between ACTS and ground based fiber optic networks or interfaces to supercomputers. Five of the HDR terminals have been built and they are allocated to the various ACTS experiments for predetermined lengths of time, then moved to another location. Because of the delay in finishing these complex groundstations, all ACTS experiments until recently used the smaller and much slower T1 portable ground stations.

The network that we are in the process of establishing runs using the ATM protocol from Caltech to Mauna Kea, Hawaii. Its overall layout is given in Figure 1. The first leg runs at OC-3 from the Caltech campus to JPL through optical fiber, then through the HDR at JPL up to the satellite. The downlink from the satellite is through the HDR in Honolulu.

We have negotiated a contract with GTE Hawaiian Telephone for a T3 link from Honolulu to the Keck Telescope on the summit of Mauna Kea, with a drop at Keck headquarters in Waimea. The completion of the underwater inter-island fiber optic cable in early 1995 by GTE Hawaiian Telephone was an important step towards making this network possible. There are serious problems in the capacity of existing equipment in the link between Waimea and Hale Pohaku, a point half way up Mauna Kea, after which fiber optic cable has already been laid to the summit. Plans to upgrade this segment have been under discussion for several years, and sources for the necessary funding exist since part of this segment services all the astronomical facilities on Mauna Kea. However, their implementation has been delayed far beyond the point anticipated at the time we proposed our ACTS experiment.

Because of these limitations, our network runs through some existing telephone company microwave stations along the Saddle Road and then from the Saddle Road up to Hale Pohaku through two portable microwave antennae which GTE Hawaiian Telephone has provided specifically for this project

Several vendors are supplying ATM hardware for this network. Newbridge Networks supplied the ATM switches used by GTE Hawaiian Telephone, while JPL uses Fore Systems switches, and the Caltech switch is made by SynOptics. Fore ATM SBus cards are used as the interface into the Sun SPARC 20/51

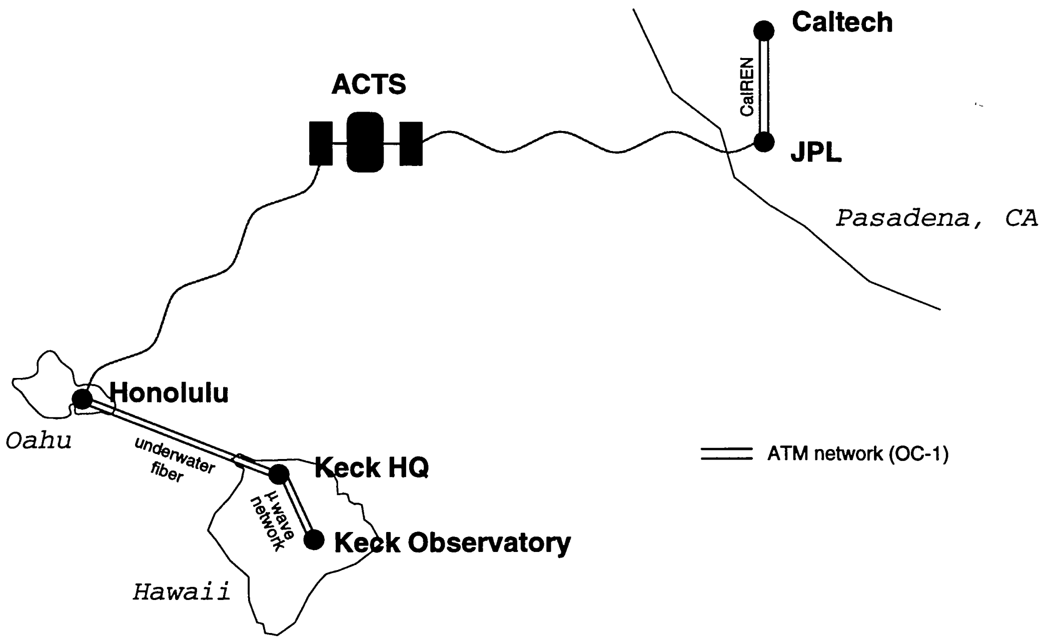

Figure 1. Layout of the high speed network used for remote observing with the Keck Telescope.

workstations at each end of the network. This mixed vendor environment is a stringent test of the compatibility among these vendors in the relatively new ATM environment. It will also be of interest to see how well ATM performs in a network with so many different physical media, from satellite links to microwave, as well as the usual optical fiber.

3. The Current Status of the Network

The HDR at JPL, which services several ACTS experiments, has been installed and is in the process of being debugged. The HDR in Hawaii is in the process of being installed at the Tripler Medical Center in Honolulu to service a remote medical diagnostics experiment and our Keck experiment.

At the current time (November 1995), the DS3 link between Honolulu and Hale Pohaku is operational, the link between Caltech and JPL is operational, and efforts to debug the HDR at JPL are underway. By January 1, 1996, we expect the network to be operating and fully debugged. Remote operation from Waimea on the Big Island of Hawaii, the location of the Keck headquarters, to the Keck Telescope will be routine and efficient, while remote operation of the telescope and its instruments from California when the satellite is available should have begun by then as well.

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