Telemetry for Remotely Monitoring Vehicle and Bicycle Counters

INVENTORY AND MONITORING
NATIONAL TECHNOLOGY & DEVELOPMENT CENTER

George Broyles Project Leader
Ted Etter Electronics Engineer

For Additional Information Contact: Program Leader, Inventory & Monitoring, San Dimas Tech & Development Center,
444 East Bonita Avenue, San Dimas CA 91773-3198; Phone 909-599-1267; TDD: 909-599-2357; FAX: 909-592-2309
IBM: Mailroom/wo,sdtdc FS web: http://fsweb.sdtdc.wo.fs.fed.us E-mail: Mailroom/wo_sdtdc@fs.fed.us

Highlights

- Vehicle and bicycle counters often are located far from Forest Service offices.
- Telemetry systems can be established to allow data from those counters to be downloaded automatically to a computer in Forest Service offices.
- This same technique could be used to transmit data from other remote data loggers to Forest Service offices.

Introduction

Successful recreation management relies on knowing visitor use patterns; where visitors are going and how many are at certain areas during specific times of the day and seasons. Gathering this information can be expensive using traditional methods, especially when recreation sites are scattered across administrative units. This project identified methods that could accurately count mountain bike and vehicle traffic. We automated the collection of visitor use counts so it could be transmitted to Forest Service offices for daily review and analysis. This process should provide recreation managers with the information they need to track the use of trails, roads, and recreation sites.

Knowing visitor-use patterns should allow for better management decisions, such as decisions to improve, close, or simply maintain certain recreation facilities. Now, visitor counters often are read monthly and the data are entered manually in computer records sometime later. Automation can improve efficiency. Daily counts allow use patterns to be related to factors such as weather and time of day.

The telemetry project for vehicle and bicycle counters was designed to demonstrate the capability of retrieving data automatically from remote sites, reducing the time required for Forest Service personnel to drive to data collection sites and download data from the counters.

Counters and telemetry equipment were installed at two sites in the Land Between the Lakes National Recreation Area in western Kentucky and Tennessee. The area is administered by the U.S. Department of Agriculture Forest Service. The project included the creation of software that would retrieve data over the Forest Service's existing VHF (very high frequency) repeater network at a time of day when the network normally would be inactive. The hardware that linked the data loggers in the field and computer in the office to VHF FM radios was identical to the hardware developed for the Pacific Southwest Research Station in Fresno for the station's Kings River watershed study. A new mountain bike counter from TRAFx Research in Alberta, Canada, was evaluated during this project.

Telemetry Hardware

Components were designed or selected so that persons could use the same software in the office that they would have used in the field when retrieving data. Examples of such software include *Loggernet* for Campbell Scientific products and *Flowlink* for Isco water samplers.

The Bendix-King EPH and GPH5100 series radios were selected for the telemetry. These radios could be purchased under an existing contract with the manufacturer, RELM, and have long been used in the Forest Service. The radios were ordered with a BNC connector that connected to coaxial cables from high-gain antennas. The antennas were about 40 feet away from the radios.

Teledesign TS2000 modems converted serial digital data from the data loggers and the computer

to an audio format that could be used by the radios. These modems were connected to external speaker and microphone terminals on the radios, providing RS-232 serial data connections for the computers and data loggers. The modems were programmed to pass data over the air at 1,200 bits per second.

Figure 1—The telemetry equipment was housed in locking boxes manufactured to the National Electrical Manufacturers Association's standards.

Modem, Radio, and Interface Box for the TRAFx Research Mountain Bike Counter

The process of selecting one remote data logger among many was handled by two custom circuits and some software on the office computer. The circuit (known as the *PC Link*) that connected to the office computer generated DTMF (dual tone, multiple frequency—or *touch tone*) signals after the PC software selected a site for communication with the office computer or put the communications hardware to sleep. Another circuit at each site, known as the *Radio-Modem Interface*, responded when a tone sequence matched its address. This circuit allowed the radio to connect with the modem and transfer data.

Telemetry Software

Three custom software applications were developed to help implement the telemetry system:

- **AutoPoll**, an application to initiate data downloads automatically from the counters
- **Dialer**, an application to wake a selected telemetry link so the counter could be configured remotely

- **ToneGenerator** for issuing DTMF tones manually from the PC for testing and troubleshooting the DTMF circuits

To avoid tying up radio airspace with data downloads during office hours, a custom software application was developed to automate the download process. This software application, *AutoPoll*, could be scheduled to download the data during the early hours of the morning, when the squeaks and squawks of data downloads would be less disruptive. *AutoPoll* generates the DTMF tones required to activate the radio interface for a given counter, issues the commands required to download the counter's data, waits for confirmation that the data was successfully downloaded, and issues the DTMF tones to put the counter's radio interface back to sleep. This process is repeated for each counter. After download attempts have been completed for all counters, if any downloads were unsuccessful, two more attempts are made to download the data.

A log file is created for each nightly download cycle, recording the success or failure of the data download for each counter. The log will allow the user to try to resolve any problems that might have caused downloads to fail (loss of power, antenna adjustment, and so forth). All data is stored on the counter, so once any problems are resolved, data will be retrieved during the next successful download.

Another software application, *Dialer*, issues the DTMF tones to wake up a counter and establish a serial link over the radio so the counter can be configured. This software enables users to issue configuration commands to the counter just as if it was connected to the counter with a serial cable. When configuration is complete, the *Dialer* generates the DTMF tones that put the counter's interface circuit to sleep and terminates the connection.

A third software application *ToneGenerator*, provides a graphic interface that allows a user to generate DTMF tones. This application is used to test and troubleshoot the DTMF circuits.

Vendor Cooperation

Some data loggers are incompatible with telemetry over repeaters. Often, data logger firmware or communication software is designed for a direct connection between the computer and the data logger. The computer software and the data logger expect immediate responses to transmitted messages. The time a signal takes to travel round trip through a repeater—typically, about a second—is too long for communications to be established or maintained.

The timeout period in the standard firmware of the *Pegasus* traffic counter from *Diamond Traffic Products* was too short for telemetry over repeaters, but a programmer at *Diamond Traffic Products* created a custom firmware version that allowed the communications. The TRAFx data logger had no timing constraints and worked with our telemetry system right out of the box.

Site Assessment

Several issues had to be investigated before appropriate electronic and mechanical hardware could be specified and ordered for each site. The Kentucky Lake Bridge site had both a vehicle and bicycle counter. The North Welcome Station site just had a bicycle counter. Even though the components for the telemetry system were designed or selected for solar power backed up by battery power, both sites had 120-volt ac line power, eliminating the need to rely on solar power.

The radios and associated components were installed in locking boxes (figure 1) manufactured to National Electrical Manufacturers Association specifications. The boxes were mounted close to the power outlets. Where possible, cables were brought into the boxes from the bottom to reduce the possibility that rain might leak through the opening. All cables were routed through PVC conduit.

The terrain in the Land Between the Lakes region prevented line-of-sight communication between the repeater tower in Golden Pond, KY, and the two data logging sites. Because a spectrum analyzer showed that the signals from the Golden Pond repeater were weak, six-element Yagi high-gain antennas were used to achieve the maximum signal strength.

Although the radios and interface components were near the sources of 120-volt line power, the mountain bike counters needed to be at trailheads 100 feet or so away. The RS-232 serial data communications specification provides for a maximum cable length of 50 feet. A special circuit, the *Serial Data Extender*, was designed to allow the data signals to be carried over larger distances. While a number of serial data extenders are available commercially, none could be found that included the "handshake" signals the counters required. A pair of these new circuits was installed at each site to ensure reliable data links between the counters and the modems.

Evolution of the TRAFx Research Mountain Bike Counters

The TRAFx Research mountain bike counters came as two connecting modules. The first was the data logger, and the second was the "docking module" that provided an RS-232 serial data link to the data logger. Power for the counter and docking module is imported on pin 9 of the serial port connector; data and the power ground are on pin 5.

The docking module originally required closing a manual switch before beginning communications with a computer or modem. TRAFx provided a modification that kept the docking module continuously "live" and ready to respond to commands from the modem and remote computer.

The data logger module included a potentiometer with a dial to adjust the magnetic field sensor that the module used to detect a bicycle. Although TRAFx recommends burying the data logger under a mountain bike trail, we were concerned that the data logger might have to be dug up for recalibration. Our initial installation placed the counter and serial data extender circuits inside an aluminum enclosure beside the trail. While this setup detected steel-framed bikes, it did not detect bikes with frames made from aluminum, titanium, or graphite if they were more than a foot away.

We discussed the need for a self-calibrating version of the mountain bike counter with TRAFx Research. Late in 2004, TRAFx Research developed a prototype of a self-calibrating counter. A new counter was purchased, placed it in a watertight enclosure, and buried near MTDC's office where it could be tested. The original mountain bike counter specifications had listed the counter's reliable sensing range as 1 meter. The new counter could detect an aluminum-framed mountain bike up to 4 feet away.

After the self-calibrating counter had been tested, the original counters that had been installed at Land Between the Lakes in May of 2004 were replaced with the new self-calibrating units. The new counters were installed in sealed plastic Pelican cases with Amphenol mil-spec connectors for the data cable connection. Wooden trusses were placed inside the Pelican cases so that they would not deform under the weight of riders and their bicycles. Once the data cable plugs were connected to the Amphenol connectors, the plug-connector assemblies were wrapped

in mastic tape and electrical tape to seal the connection and keep dirt out. Each Pelican case was placed inside a plastic garbage bag to reduce the amount of dirt that would adhere to it.

Figure 2—The TRAFx bicycle counter was placed in a Pelican case.

Battery Backup for TRAFx Research Mountain Bike Counters

Power outages were common at both test sites. Data could have been lost if we had not provided backup power for the counters. A battery backup circuit was designed, built, and installed at one of the sites. The backup circuit included a 12 amp-hour, 6-volt battery that could run the counter and serial data extender circuits for at least 5 days without power. The circuit provided a trickle charge for the battery when line power was present.

Configuring Two Data Loggers To Share One Radio

At the Kentucky Lake bridge site, the Diamond Traffic *Pegasus* car counter and a TRAFx Research mountain bike counter were close enough to each other that they could share a single radio, power supply, and enclosure for the telemetry hardware (figure 3). The solution for getting data from two data loggers through one radio was to use two modems and two *Radio-Modem Link* boxes. The signals from the radio were wired in parallel to the two link boxes, and the DTMF tone codes determined which link box would allow its modem access to the radio.

At this site, the Diamond Traffic *Pegasus* car counter was housed in the equipment box with the radio and telemetry hardware. Signal wires from the wire loops buried in the road nearby were routed to the wooden pole where the equipment box was mounted.

The 12-volt power supply for the telemetry hardware also provided operating voltage for the *Pegasus* counter and charged its battery.

Figure 3—The vehicle and bicycle counters shared a single radio that transmitted their data.

Antennas and Coaxial Cables

As mentioned previously, the terrain at the Land Between the Lakes required high-gain antennas for reliable communications. At both sites, wooden telephone poles were installed so the Sinclair SRL206EB six-element Yagi antennas could be mounted 35 feet above the ground. These antennas have a gain of 9.5 dBd (decibels of gain compared to a dipole), or nearly 10 times as much gain as a dipole antenna and were rugged enough to withstand ice buildup and high winds. Because the signal had to travel 40 feet from each antenna to a radio, low-loss coaxial cable (Times Microwave LMR–400) was used. A lightning arrester was placed between the radio and the antenna cable inside the equipment box.

The Yagi antennas are directional and need to be aimed correctly to receive the strongest signals. To aim the antennas, the coaxial cable from the antenna was connected to the input of a spectrum analyzer. A separate radio was used to activate the Golden Pond repeater. The repeater's signal strength was noted on the spectrum analyzer. The antenna was moved to the direction that produced the strongest signal and then was secured. This operation required two persons, one to read the signal strength on the spectrum analyzer and another on a bucket truck to adjust the antenna.

Features and Installation of the TRAFx Research Mountain Bike Counter

The TRAFx Research mountain bike counter uses a magnetic field sensor to detect variations in the earth's magnetic field created by a passing object containing ferromagnetic material (such as iron or steel). The chain, spokes, and axles on a bicycle usually are ferromagnetic, even though the frame may not be. Counting bicycles with frames that are not ferromagnetic (such as aluminum or graphite frames) requires the counter to be fairly sensitive. Users can change two settings to adjust the sensor's sensitivity. A third setting adjusts the lockout time, establishing the minimum time between counts; this setting can be used to prevent the sensor output for each wheel and the crank axle from being recorded as three bicycles.

Data logging also can be set in a variety of modes. When just a modest number of counts are expected, it is reasonable to record the date and time that each bicycle passes. If a lot of bicycles will be counted or the data isn't recovered frequently, data memory can be conserved by counting the number of bikes per hour or every several hours.

Using a Personal Digital Assistant (PDA) To Program the TRAFx Research Mountain Bike Counter

The RS-232 serial interface allows the TRAFx Research mountain bike counter to be configured with a computer or with a PDA (figure 4), using basic Pocket PC terminal software such as VxHpc, available from Cambridge Computer Corp.

TRAFx Reporter software is provided with the counters. This software allows managers to run standard reports and query the data to create customized reports. Standard reports include charts, graphs, and tables showing hourly, daily, weekly, and monthly counts.

Figure 4—A personal digital assistant (PDA) can be used to program the TRAFx Research mountain bike counter.

The Diamond Traffic Products Pegasus Vehicle Counter

The Pegasus vehicle counter from Diamond Traffic Products was selected because of its ability to communicate through a modem. Diamond Traffic Products manufactures an assortment of vehicle counters, but some models are not designed to handle remote communications protocols. Wire inductive loops had been installed previously in the inbound lane of the north entry road into the Land Between the Lakes National Recreation Area. A simpler Diamond Traffic Products vehicle counter had been tallying vehicles before this project began.

The Pegasus counter has a variety of logging options, such as the number of axles counted per vehicle and the length of the counting intervals. The counter was configured using Diamond's *TrafMan* software package. The automatic downloading software retrieved the logged data.

Another brand of vehicle counter produced by an offshore vendor was considered, but that counter did not allow data to be transmitted through a modem.

Conclusions

The vehicle and mountain bike counters successfully recorded visitor use at the Land Between the Lakes National Recreation Area. The telemetry equipment and software worked satisfactorily. However, the telemetry link was not always reliable, apparently because of problems with the Golden Pond repeater.

Acknowledgments

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Vendors and Hardware

RELM Communications, Inc.

7305 Technology Drive
West Melbourne, FL 32904
Phone: 800–648–0947
Product: GPH5101A 5-watt FM radio with option LZA0812 for a BNC antenna connection

TRAFx Research, Ltd.

6A Riverstone Road
Canmore, Alberta, Canada T1W 1J5
Phone: 403–678–1802
Web site: *http://www.trafx.net*
Products: TRAFx mountain bike counter and vehicle counters

Diamond Traffic Products

P.O. Box 1455
Oakridge, OR 97463
Phone: 541–782–3903
Web site: *http://www.diamondtraffic.com/html/volumecounters.html*
Product: Pegasus 4 Loop Interval Recording Counter

Sinclair Technologies, Inc.

55 Oriskany Drive
Tonawanda, NY 14150
Phone: 800–263–3275
Web site: *http://www.sinctech.com*
Product: SY206-SF4SNM(E) Yagi antenna, six elements, extended boom (162 to 169 megahertz)

Teledesign Systems

2635 North First Street, Suite 205
San Jose, CA 95134-2032
Phone: 800–663–3674
Web site: *http://www.teledesignsystems.com*
Product: TS2000 modem

Cambridge Computer Corp.

Web site: *http://www.cam.com*
Product: VxHpc hyper terminal from

About the Authors

Ted Etter joined MTDC in 2002 to work on electronics projects. He has spent more than 25 years working on electronic instrumentation and display technology. He received a bachelor's degree in mathematics from the University of Oregon in 1992 and a master's degree in teacher's education from Eastern Oregon State University in 1993. Before coming to MTDC, he taught courses in programming, digital circuits, data communications, radiofrequency communications, robotics, microprocessors, and operating systems at the University of Montana College of Technology.

George Broyles joined SDTDC in 2001 as a Project Leader in the Inventory & Monitoring Program. He came to SDTDC from the Black Hill National Forest where he worked in Timber Management since 1989. George received an associate's degree in Ornamental Horticulture from SUNY Farmingdale in 1977 and a bachelor's degree in Sociology from Black Hills State University in 1990.

Library Card

Broyles, George, Etter, Ted. 2005. Telemetry for remotely monitoring vehicle and bicycle counters.

Describes the development and testing of equipment and software used to automatically download data from a remote vehicle and bicycle counter over a radio link to a Forest Service office. Three custom software applications were developed: AutoPoll, an application to automatically initiate data downloads from the counters; Dialer, an application to wake a selected telemetry link so the counter could be configured remotely; and ToneGenerator for issuing dual-tone multiple frequency tones (commonly called touch tones) from a PC to test circuits using those tones. Data from counters installed on roads and trails in the Land Between the Lakes National Recreation Area were transmitted from the counter during the late evening and early morning hours when radios were not being used for other purposes.

Keywords: antennas, data loggers, Diamond Traffic Products, Land Between the Lakes National Recreation Area, mountain bikes, radios, RS-232 serial data connections, software development, TrafX Research, visitor use