Wireless solar radiation and meteorological instrument for K-12 Technology Education

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Abstract

A wireless network of weather stations is being designed for a project to enhance and advance mathematics, science, and computer education for K-12 students. In this network, portable, solar powered weather stations incorporating GPS and spread spectrum radio communication features will be deployed on rooftops of 53schools in the area surrounding the University of Texas at Brownsville (UTB). Data will be gathered at a central station by radio and transmitted to UTB via Internet at regular intervals and, after its quality has been properly assured and qualified, uploaded to a specifically designed web site. Students in the schools will access the web site and use the acquired high-quality data to derive information regarding solar radiation availability, the movement of weather systems through the region, and the development of weather systems within the area. Depending on the grade level of the classes, activities will include calculation of the velocity of weather systems, weather forecasting, correlation of cloud types and weather, statistical operations on wind and weather system data, calculation of cooling and heating degree days, -- etc. In a concerted effort among K-12 students, educators and UTB faculty, the acquired solar and meteorological data will also be used for calibration and fine-tuning of satellite models of ground-level solar radiation estimates. The involvement of K-12 students, and their educators, in such a relevant scientific endeavor is expected to raise their interest in science and technology.

This paper sketches the complete concept of the educational weather station network being proposed, and discusses its educational and research potential.

Manufacturing engineering technology and electronic engineering technology students are involved in the design and implementation of the network. They will be deeply involved in the deployment of the educational weather stations, in visits to schools to instruct K-12 students in maintenance and operation of the stations, and to assist students in their meteorological instrument based projects. It is anticipated that these interactions will comprise service learning experiences and projects for the engineering technology students, and outreach and recruitment activities for the department.

Overview

A weather station network is proposed for installation on the rooftops of, or in an accessible area to, each school in the Brownsville Independent School District (BISD). The school district includes 53 schools, including elementary, middle, and high schools. The weather station at each school will collect data every second and transmit sixty seconds of data each minute to a central receiving station by spread spectrum radio. The central receiving station will be located at the BISD administrative office, which is centrally located with respect to all schools in the district.

The central receiving station will collect and assemble the data from all 53 weather stations and transmit that information via Internet, using standard file transfer protocol (FTP), to the main database server at the University of Texas at Brownsville (UTB). The server will permanently store all data from all stations. The data will be checked for coherence before storage. Each school may inquire the UTB database for any data for any purpose.

Each school will be encouraged to publish its own data or weather projects on the Internet. Science and mathematics faculty at each school will be presented with access to lesson plans and support to use the weather station as a major adjunct in teaching science, math, and technology concepts and practice.

The School Weather Stations

The main purpose of the weather stations that will be located at all BISD schools is to gather information relative to a number of physical parameters such as wind speed and direction, solar horizontal global irradiance, atmospheric pressure, relative humidity and dew point, ambient temperature, time, and position.

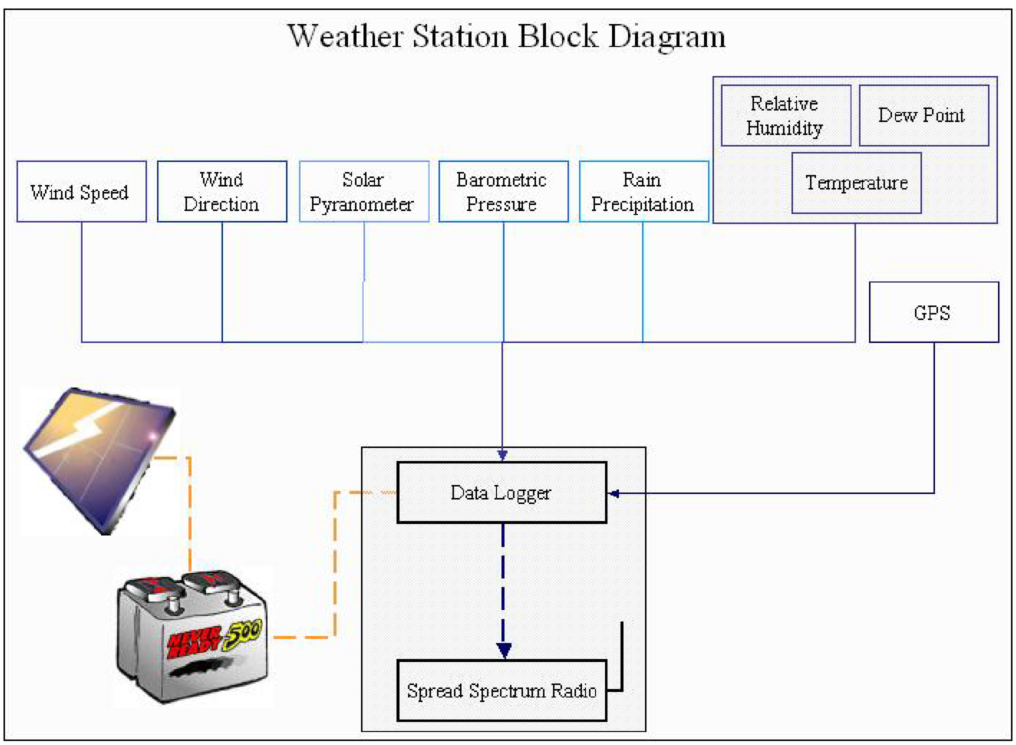

Figure 1: Weather Station Block Diagram

To achieve its purpose, every station will be equipped with an identical set of sensors, a data logger, a spread spectrum radio, and a photovoltaic power supply. The data logger will collect the information coming from each sensor and transmit it to the central weather station through the spread spectrum radio. A schematic view of the weather station is depicted in Figure 1.

The GPS device is responsible for the time and position synchronization of each weather station. The GPS data will not be transmitted to the base station at the same frequency as the data from the meteorological sensors. In fact, time is the only GPS parameter that will be transmitted at the same frequency at the weather data. The GPS time is a common time reference for all the weather stations. For projects such as tracking weather changes, it is important that the data from all stations be recorded with respect to the same clock. Data logger and PC clocks will vary considerably with respect to one another. GPS provides a simple solution to the data synchronization problem. Position will be transmitted only when a change with respect to the previously reported position is detected. This would occur, for example, when the station is removed for calibration.

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Regarding the amount of bytes that each sensor needs to store information in the data logger, the estimate is shown in Table 1.

Table 1. Size in bytes of weather sensor data

Parameter	Bytes
Wind Speed	2
Wind Direction	2
Rain Precipitation	2
Solar Radiation	2
Relative Humidity	2
Dew Point	2
Temperature	2
Atmospheric Pressure	2
GPS Time + Position	4+50

The weather sensors shown in Figure 1 are all available from Campbell Scientific, Inc. as shown on the list of Table 2. This table shows only a selected set of sensors from one vendor. Alternative choices are available and may be substituted.

Table 2. List of weather station equipment.

Weather Station Equipment	Campbell Scientific Part Number
Datalogger	CR 10X
Wind Speed and Direction	03001 Wind Sentry
Solar Pyranometer	CM3
Barometric Pressure	CS105
Rain Guage	TE525
Temperature and Relative Humidity	C500
Geographic Position	SV8PLUS
Spread Spectrum Radio Modem	RF400
10 Watt Solar Panel	MSX10
Battery and Charge Regulator	PS12LA

Network Configuration

The distribution of the stations has a very important role in the project. Limitations of the spread spectrum radio transmitter dictate that the distance between any station and the main station will be less than 12 miles. The main station will be located in a central position with respect to the distribution of the schools in the district. Fortunately, the administrative offices for the Brownsville Independent School District (BISD) are in the geographic center of the city. The most distant school is approximately 8 miles from the main station.

Given the distribution of the stations, the number of weather stations, and the features of both the data logger and spread spectrum radio, every weather station will transmit data each minute. In this way the central station computer will gather all data within 53 seconds, and it will have seven seconds to download the current amount of data as an ASCII file via Internet to the UTB computer. This is sufficient to complete the downloading process before starting another data collection cycle.

These frequency transmission considerations are based on Campbell Scientific Inc. products. Each weather station data logger has a memory of 128 kBytes, and each spread spectrum radio has a data transmission capability of 9600 bps.

The same routine that generated the ASCII data file will open an FTP (File Transfer Protocol) connection with the main server to perform the data transfer operation. If the FTP operation is successful, the file will be copied into a special directory (incoming-file) and the source moved into a directory (transferred-file) located on the secondary server. This directory will be cleared once a week. The success of the FTP will be certified by an acknowledgement bit, sent by the main server to the secondary server. If the process fails, the secondary server will perform another attempt instantly. If the second attempt also fails, the file will be moved into another directory (refused-files), which will be re-processed once a day and emptied afterward regardless of the final result of the transfer. To track each step a log file will be created both on the secondary server and main server side.

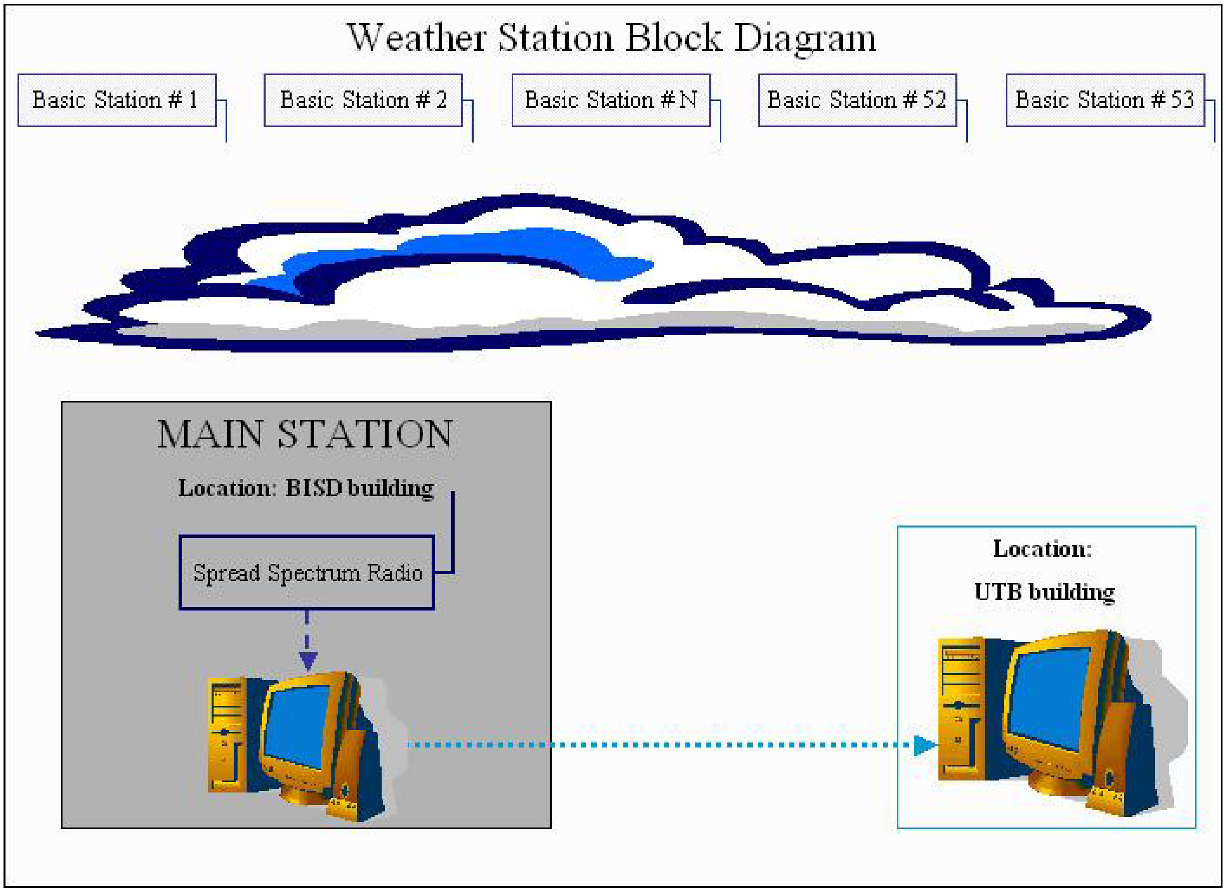

Figure 2: Weather Station Distribution

On the main server side, an *ad-hoc* designed batch procedure will process the text files contained in the incoming-file directory. This routine will take data contained in the current text file and will analyze them in terms of integrity, consistency and coherency. Once controls are done, the same procedure will insert data into the main database, where they will be available for further manipulation, and will delete the current text file. If during the verification phase an error should occur, the procedure will perform another attempt instantly. If the second attempt also fails, the file will be moved into another directory (refused-files), which will be re-processed once a day and emptied afterward regardless of the final result.

Once in the main database, the new data must be validated and cleaned. This task will be performed by a stored procedure. Its launch can be scheduled or run by means of a trigger. Regarding the logic implemented into that stored procedure, this will take into account previously stored data and some reference values obtained from the meteorological weather center in Brownsville. The procedure will compare current data with previous data from the same weather station as well as from different weather stations.

At this stage, cleaned and validated data will be available for display and manipulation. On the main server side a portal will be designed and built in order to show data and perform some queries on the database. This web site will be accessible from each school belonging to the Brownsville Independent School District, and students can retrieve and manipulate data, implement several kinds of queries, create graphs and perform calculations on the stored data.

Educational and Research Potential

The weather station system will be used in K-12 education. The National Science Foundation (NSF) is the sponsor of two web sites that will be used in combination with activities related to the school district weather system.

The National Science Digital Library (NSDL) [1] and the Digital Library for Earth System Education (DLESE)[2] are both NSF supported. NSDL is a source for course material K-12 and a virtual community for developing course material. DLESE is an open Internet library of material produced by and for students at all levels.

The Atmospheric Visualization Collection on the NSDL web site[3] provides a wealth of information for course and lesson plan development.

Specifically regarding the use of the weather station network, we believe that it will be an important adjunct to lesson development. The NSDL web site lesson plans instruct the teachers to have the students use instruments in an NSF network or instrument set. It also makes use of clever Java applets to illustrate concepts. However, the instruments and demonstrations are all "virtual," pictures of instruments in the ARM network and computer generated pictures of natural phenomena. Likewise, the data is also "virtual," downloaded from remote databases, although, since data are numbers from instruments, there is a level of abstraction whether the data comes from real instruments that a student can touch, or from distant instruments.

With an instrument set on the rooftop of each school, students can touch the hardware; see how it works, and work with locally produced data. This local instrumentation will enhance the experience of manipulating data and provide a clear mental pathway to understanding that there are instruments for measuring some atmospheric data that is not in the local package but whose data may be manipulated using techniques learned on the local instruments.

Concurrent to developing lesson plans based around the local weather station network, and to adapting NSDL plans to also include our local data, there will be an effort to develop hands-on demonstrations to provide a smooth access to the Java applets available on the Internet.

With less work than developing lesson plans, plans for many lessons can be found on the Internet. For example, The Nebraska Earth Science Education Network has developed a group of lesson plans for elementary levels, including excellent introductions to thermometers and thermometry and to wind and anemometry.[4]

Elementary school students can build entire weather stations[5,6]. They can use their class weather stations, relate them to the rooftop systems on their school, and then begin to understand the operation of the whole network using existing lesson plans modified a little.[7] Using rooftop weather station data, students could learn data taking and experience field work and issues involved in data collection. They could take temperature and sunlight data and record them, then plot temperature as line graphs and as bar graphs. They could learn to average hourly temperature data to obtain daily data. They could learn about data maxima and minima.

In middle schools and high schools, temperature and barometric pressure data can be used to plot and predict movement of weather fronts. Students could compare data from their rooftop station with data from other schools across the city, which are available at the weather web site, and plot direction vectors for temperature fronts and pressure fronts.

At higher levels, there is research to be done in a variety of areas. For example, the Brownsville area, and surrounding communities within the service area of the University, will provide important solar radiation information that may be used to verify or calibrate remote sensing by weather satellites. Such research might attract external funding for graduate research or upper undergraduate research. Annual visits to each school to retrieve weather stations for calibration, and the calibration, would be metrology projects for electrical engineering students. Visits to schools by engineering technology students for the purpose of educating teachers and science students about the weather station and assisting in Science Fair projects would constitute service learning projects. Such visits would help hone oral communication skills, and community outreach skills, which engineering and engineering technology students need.

Conclusions and Future Work

The configuration of the weather station system is defined. This definition will allow engineering technology students to refer to catalogs to complete the detailed mechanical and electrical design of a weather station. Then manufacturing engineering technology students can plan the construction of fifty three systems, and design brackets and hardware systems that may reduce cost and improve flexibility. Students in electronic engineering technology, with an interest in programming will write the weather station programs, the central station computer program, and the UTB server computer program.

The authors will continue to seek funding for the system from a variety of funding sources, while developing contacts with the BISD science and mathematics education programs. Funding sources are also being sought for the graduate level research projects that we anticipate doing.

References

[1] http://comm.nsdlib.org/, portal for the National Science Digital Library, a project funded by the National Science Foundation.
[2] http://www.dlese.org/, Digital Library for Earth System Education, a project sponsored by the National Science Foundation.
[3] http://avc.comm.nsdlib.org/cgi-bin/wiki.pl, Atmospheric Visualization Collection of lessonplans, National Science Digital Library.
[4] http://nesen.unl.edu/lessons/weather/pritemp.html, http://nesen.unl.edu/lessons/weather/priwind.html, developed by Susan Frack and Scott Prickett, Conservation and Survey, UNL, July, 1996, sponsored by the Nebraska Earth Science Education Network (NESEN), Email: dgosselin2@unl.edu, 113 Nebraska Hall, Univ. of Nebraska-Lincoln, Lincoln, NE 68588-0513

[5] http://www.miamisci.org/hurricane/weatherstation.html. Available in CDROM, Hurricane Storm Science CD-ROM, Miami Museum of Science, 3280 South Miami Avenue, Miami, FL 33129.

[6] The Franklin Institute Online, Make Your Own Weather Station, http://sln.fi.edu/weather/todo/todo.html,

[7] http://www.remc11.k12.mi.us/bstpract/bpIII/030/030.PDF, from the Best Practices of Technology Integration in Michigan Site (http://www.remc11.k12.mi.us/bstpract/). This site is sponsored by the Michigan Association of Intermediate School Administrators, the REMC Association of Michigan, and the Great Lakes Educational Network (Glen). The lesson plans are available on CD.

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