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THE WIRELESS DATA ACQUISITION SYSTEM FOR FLOOD CONTROL AND WATER MANAGEMENT

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Abstract: The probability of flood occurrence is a global problem that is dependent on meteorological processes and local conditions in a particular area. Therefore, flood control and water management information is divided into two distinct activity areas and are crosslinked where appropriate. One area deals with monitoring water levels in mountain streams, rivers, canals, reservoirs or water conservation areas. An operating control of multi-purpose spillways, locks, culverts and reservoir dams should be considered in this area. The second area deals with meteorological activity which is set up to disseminate the information about weather conditions such as: weather reports, forecasts, rainfall amounts, and wind data. In the paper, we describe a radio link data acquisition as a technical and information system with territorially distributed properties. The considered system is composed of meteorological and water subsystems. An interconnection and communication between this two elements are the crucial element of the entire system.

Keywords: data acquisition, data transmission, computer applications

1. INTRODUCTION

The probability of flood occurrence is a global problem that depends on meteorological processes and local conditions in a particular area. Therefore, flood control and water management information are divided into two distinct activity areas and are cross-linked where appropriate.

Complex system decomposition into a set of smaller subtasks, so that an overall solution can be found easily, is well known. Many authors considered the accurate conditions of such a functional or structural decomposition and proposed various solutions. Generally, there is no doubt that such an activity increases the number of communication interconnections. One area deals with monitoring a water level in mountain streams, rivers, canals, reservoirs or water conservation areas. An operating control of multi-purpose spillways, locks, culverts and reservoir dams should be considered in this area.

The second area deals with meteorological activity which is set up to disseminate the information of weather conditions containing weather reports and forecasts as well as rainfall amounts swelling the rivers and wind data.

Given the vast territory that the systems under discussion cover, the most economical solution is to use radio channels for communication. This is why we focus our discussion on this type of communication.

The existing structural and functional divisions are considered as given in both systems. We now focus our attention on communication within and among subsystems. We proceed to present concepts for coupling the systems using information channel layer. The concepts are based on the assumption that structural and fuctional relationships should be reflected in the communication layer (Schat 1994).

2. PROBLEM FORMULATION

Activities in each of the above mentioned aspects require specific information resources so that correct reasoning can be carried out. In the first case, the reasoning leads to forecast, in the second case, to control decisions. In each case the scope and amount of information that guarantees at least observability of the systems under consideration is different. For meteorological systems, controllability cannot be considered at all. For hydrological systems, controllability requires long time intervals. This requires that we store and aggregate more data.

These are not the only differences between these systems. In meteorological systems, information (when turned into a forcast) is disseminated to all interested parties. In hydrological systems, information that is turned into control decisions is selectively sent to control points. The first one works in a broadcast mode while the second works in an addressed mode.

The time-based nature of information is an additional distinguishing characteristics of the above systems. In a normal mode, data in hydrological systems are much more stable than those in the meteorological systems. However, in a crisis situation (especially in mountainous regions), hydrological data change very rapidly while meteorological data are stable. In the solution we present below, we focus on increasing the communication channels' throughput in both systems. Our solution takes into account the differences between the systems while at the same time considering their interactions.

In conventional solutions, both systems gather data through separate channels. The channels' throughput is determined based on the highest possible user's demand. However, in practice, the highest demands are shifted in time. If the two information channels were to be combined into one with the capacity equal to the sum of the capacities of the two channels, then each system would have at its disposal a channel with a higher throughput that the algebraic division into two parts would indicate. This is due to the time shift mentioned above. The use of radio facilitates communication based on a common information channel. Moreover, there are additional benefits afforded by this solution, for example, some information that is collected in one system and needed in the other one, is made available automatically (through stand-by). (In the case of separate channels, a transmission procedure would have to be employed).

Data acquisition stations in the hydrological system are associated with water reserviors and rivers. Therefore, such stations are typically located in low lying areas. Radio transmission in such cases is quite difficult. Repeaters are then required. Their location is based on terrain features. However, they are always located on hills or mountain peaks.

The meteorological data acquisition stations in mountainous areas are typically co-located with the repeaters. Thus, if we assume that those systems have common communication channels, then we can postulate that each data acquisition station be a digipeater as well. This would eliminate the need for repeaters that are used just to forward transmission data. Therefore, the hydrological and meteorological systems have not only common functional but also structural layers (at the level of communication channels).

3. COMMUNICATION SOLUTION

The considered system is composed of meteorological and water management subsystems. An interconnection and a communication system between these two elements are crucial. Concerning the communication aspects, our solution is based on a packet radio network application under AX.25 standard based on the CCITT X.25 orders. The AX.25 protocol meets ISO Standard 3309, 4335 and 6256 High Level Data Link Control (HDLC). So, the communication subsystem is realised in accordance with the AX.25 standard which assures the digital data transmission between stations.

The radio network for data communication proposed above provides a number of benefits as a bi-directional and reliable digital communication means necessary for data exchange and control.

The individual data acquisition meteorology stations as well as water level monitoring are most often dispersed over a wide area in the range of many kilometers. Their connection through the existing phone subscriber lines is much more expensive (Motorola, 1994) than radio communication channels. This is due to the realization and maintenance costs as compared with the costs of using radio channels. Thus, wireless communication is clearly advantageous.

The AX.25 protocol adopted in our system assumes that a communication subsystem will include a network of nodes which exchange information among each other using package commutation. Each communication node equipped with RTU (Remote Terminal Units) is provided with a TNC (Terminal Node Controller) including two basic components: an AX.25 protocol microprocessor controller and a modem.

This communication subsystem has the following properties:

- high reliability of digital data transmission;
- low maintenance costs;
- automatic transmission mode;
- easily extendible structure.

3.1. Communication protocol

The RTU stations are responsible for data acquisition but their communication properties are strictly dependent on the properties of TNC which provides proper communication interfaces for each monitoring station. The data transmitted are grouped into packages containing the CRC-16 control word. When the receiving station recognizes a data error, it demands that the packet be retransmitted. This can be done a pre-determined number of times so that correct data transmission can be ensured. Each station has its unique network address. The typical communication system uses single radio band (simplex transmission). Therefore, the important role of the node controller is to detect and to avoid the collision in case two or more stations are trying to transmit simultaneously (Jeong et al. 1995). For this purpose we implemented CSMA/CD media access method.

The TNC node controller provides the following services:
- it determines the station's address, connecting and disconnecting data transmission ,
- it discovers and corrects transmission errors,
- it detects and avoids collisions during data transmission;
- it converts digital signals to analog ones and vice versa;
- it plays the role of a digital retransmitter.

The communication between two nodes carries out the following tasks:
- connection initiation;
- data transmission (possibly duplex);
- disconnection.

The connection may be initiated by any station but the master-slave manner is preferred. Thus the following rules are established:
- the normal mode: the connections are realized by the monitoring station (master) within the determined interval;
- emergency mode: the connections are realized by the measurement stations (slave) in case of needs (e.g. emergency, exceeding of critical head values).

3.2. *The range of the communication system*

In case of the radio communication system, the transmitter power on the level of 1 Watt and good receiving conditions, the range of the transmission in UKF diapason is equal to the optical horizon (between 30 - 50 km). Therefore it depends on the antenna installation's height. When the stations are not visible, it is necessary to use a digital transmitter (digipeater). The node controller, besides its standard functions, can be used as a digital transmitter. It means that the controller automatically transmits from one node to another, just like a digital transmitter that can use any station or node controller. Hence, if two stations are out of the transmission range, they can realize connections through other stations or retransmitters.

It should be pointed out that it is important to place the node controller in a point of high altitude. Due to this placement, the range of the retransmission will be widely increased which is especially easy to achieve in mountainous areas.

4. THE SYSTEM STRUCTURE

The wireless data transmission system described here uses multi-master slave technique. The structure of our system is based on Flood Control Districts (FCD) which take a role of masters collecting data from Data Acquisition Stations (slaves) localized in spares points in the Lower Silesia Region.

The master stations ask slaves according to an established schedule securing that the maximum cycle time will not be exceed.

In an emergency that requires an immediate transmission of data to PSD in a subordinate station, this state can stop polling and can send its own data by preempting the transmission schedule. Our concepts envision a realization that consists of fourteen precipitation data collection stations and ten hydrometric stations.

Each station can realize the following functions:
- measurements (precipitation, temperature, water level, etc.),
- short term data
- monitoring the operation of the station's subsystems,
- radio transmission and re-transmission of data to higher level systems,
- supply of power to all the subsystems,
- system security,
- autonomous operation of each subsystem.

5. DATA ACQUISITION STATION

In the Klodzko Valley region (Lower Silesia) fourteen meteorological stations and ten hydrometric stations will be located. The core element of each station is the controller. It takes all measurements and controls each subsystem.

Data about faults in the station's operation that are detected by the controller are sent via radio transmission to the closest dispatching station. This allows the dispatch station to take an appropriate response immediately.

Using the controller facilitates an expansion of a station (for example, to take additional measurements) and an easy modification of its functionality. For example, the station which is a transmitter can become a transceiver. The solution we have proposed is a C167CR 16bit, single chip Siemens microcontroller (Simens 1996). This device is particularly well suited to our application as it provides an excellent intelligent on-chip peripheral subsystem. The ability to connect this microcontroller to various peripherals such as RS-232, I^2C, 1-Wire or CAN guarantees extensibility of the station.

Each meteorological station uses multiple sensors to gather weather data and assures real time information output about wind direction and speed, temperature, humidity, solar radiation, barometric pressure or rainfall rate. All weather sensors communicate with microcontroller using 1-wire bus (TWI Inc.).

They are intelligent digital devices that have calibration information, unique serial numbers and sensor type information stored in the memory of each sensor.

The sensor equipment of hydrologic station is more simple, so in that case we measured only the water level and velocities. In the future this equipment range will be enhanced by water quality sensors measuring temperature, pH, dissolvent oxygen etc.

From a design standpoint, each stations are uniform. They have identical subsystems. The controller can have a display which serves as an interface for service personnel. The stations are equipped with an emergency power supply system (UPS). Each station can be installed in a location that can be different from that of the data acquisition equipment. This is particularly important in hydrological systems where flooding can occur.

6. CONCLUSION

The proposed wireless data acquisition system provides area-wide meteorological and hydrological support services to local government. In this article, we described the flood control and water management from a technical point of view. But in fact they are very complicated ecological problems. The government and local authorities (Pima County FCD) need detailed hydraulic, meteorological and ecological analyses based on a long term observation for activities such as floodprone land acquisition, flood awareness floodplain or water resources management. „Effective monitoring expands the databases, facilitates future restoration efforts and savers money. While project modifications are increasingly expensive as the planning/design process proceeds, they are less costly than those implemented after construction has begun. Contingency measures-necessitated by site-specific conditions or unforeseeable circumstances may similarly be unavoidable, but that are the necessary costs to satisfy permit requirement and guarantee a successful project"(Young and Wahl 1999).

For this purpose, it is necessary to provide the data acquisition system and database structure which allows us to use computer-based data analysis programs. Computer-based modeling (HEC 1982) and simulation of flood control and water management systems (Fedra and Jamiesson 1996) will be not be effective without good real world data collection.

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