Abstract: Many wide-area industrial systems are spread over large geographical regions, and need to be monitored and controlled from a central supervision point using SCADA systems. Long-range, low-data-rate communication is an intrinsic part of such systems. Traditionally, data communication has been established via leased lines or some other dedicated communication channels, which could be expensive and difficult to establish in certain geographically isolated regions. With the introduction of professional cellular wireless communication networks, such as TETRA, it has become possible to use their data communication services to connect remote units of a SCADA system to its supervision center. However, existing SCADA systems are often not directly compatible with wireless mobile stations and an additional protocol converter is needed to connect them. The paper deals with this issue and describes a protocol converter designed for the SCADA system of the Slovenian gas distribution system.

Key-Words: SCADA, TETRA, SDS, Digital data transmission, Protocol converter

1 Introduction
There are many wide-area systems spread over large geographical regions that need to be monitored and controlled from a central supervision point. An example is a gas pipeline system. It consists of a number of metering, regulating, and compression stations that are monitored and controlled from a supervisory center. Such monitoring and control systems are called SCADA (Supervisory Control And Data Acquisition) systems. They involve long-distance communication to transmit data between the remote stations and a supervision center. Traditionally, this communication has been established with leased lines or some other dedicated communication channels, which have often been difficult and expensive to build and operate.

With the introduction of professional cellular wireless communication networks, e.g. TETRA (TErrestrial Trunked RAdio), it has become possible to establish such communication links much more easily, assuming the area is covered by the signal. However, the communication support in an existing SCADA system is often restricted to leased-line modems, which has been the traditional way of doing communication in the past.

In this paper, we demonstrate how an existing SCADA system, used in the Slovenian gas transmission system, can use TETRA for data communication.

2 SCADA system
A SCADA system is an industrial measurement and control system consisting of:

- A central host or master (also called a master station, master terminal unit, or MTU).
- One or more field data gathering and control units or remotes (also called remote stations, remote terminal units, or RTU's).
- Software used to monitor and control the whole system.

Contemporary SCADA systems have mostly open-loop control characteristics and utilize long distance communication with relatively low data rates. The master station itself often consists of two separate subsystems:

- A workstation which processes all the information and where the system operator can monitor and control the system.
- A communication controller, which takes over the burden of real-time, low-level communication processing and network management, relieving the workstation for other tasks.

A typical SCADA system structure, as described above, is depicted in Fig.1. For long distance communication, the communication controller and RTU’s are equipped with modems (e.g. according to standard ITU-T V.23 [3] with 1200 bits/s maximum data rate). For local connections, the modems can be bypassed and EIA232 (RS232) signals used directly.
TETRA uses three different standards for voice or data transmission:
- **V+D (Voice+Data).** This standard is used for voice calls and various modes of data transmission (Circuit Mode, SDS, or Packet Data).
- **DMO (Direct Mode Operation)** is similar to V+D but operates without a base station. The set of available services is restricted compared to V+D.
- **PDO (Packet Data Optimized).** As the name implies, this standard is specially designed and optimized for packet data transmission.

Tables 1 through 3 summarize different TETRA data transmission modes and standards.

### Table 1  TETRA data transmission, circuit mode

<table>
<thead>
<tr>
<th>Error protection</th>
<th>Data rate (kbit/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1-slot</td>
</tr>
<tr>
<td>high</td>
<td>2.4</td>
</tr>
<tr>
<td>low</td>
<td>4.8</td>
</tr>
<tr>
<td>none</td>
<td>7.2</td>
</tr>
<tr>
<td>V+D</td>
<td>✓</td>
</tr>
<tr>
<td>DMO</td>
<td></td>
</tr>
<tr>
<td>PDO</td>
<td></td>
</tr>
</tbody>
</table>

### Table 2  TETRA data transmission, SDS

<table>
<thead>
<tr>
<th>Message length (bits)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>V+D</td>
</tr>
<tr>
<td>DMO</td>
</tr>
<tr>
<td>PDO</td>
</tr>
</tbody>
</table>

### Table 3  TETRA data transmission, Packet Data

<table>
<thead>
<tr>
<th>Protocol</th>
<th>CONP</th>
<th>SCLNP</th>
<th>PDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>V+D</td>
<td>✓</td>
<td>✓ (Ver. 1)</td>
<td>✓ (Ver. 2)</td>
</tr>
<tr>
<td>DMO</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>PDO</td>
<td>✓</td>
<td></td>
<td>?</td>
</tr>
</tbody>
</table>

3 Data transmission in TETRA

TETRA [1] is a professional wireless voice and data communication system, similar to GSM but with the distinct features (e.g. group calls, call priorities, direct mobile-to-mobile communications without a base station, etc.) required by professional users (police, fire brigades, etc.). TETRA standards are available from ETSI (European Telecommunications Standards Institute) [2].

3.1 TETRA Data Transmission Modes and Standards

Three different data transmission modes are available in TETRA:
- **Circuit Mode.** A fixed data communication channel is established between two points. A fixed data rate of up to 7.2 kbit/s per channel (see Table 1) is assigned to a connection. Since data transmission is normally bursty by its very nature, this mode can be quite inefficient from the viewpoint of channel usage, and hence expensive.
- **SDS (Short Data Service).** This is a special service, similar to SMS in GSM, suitable for low data rate packet transmission.
- **Packet Data.** This is fully featured packet data communication suitable for IP (Internet Protocol) traffic. The single channel net bit rate is 4800 bits/s.
CONP (Connection-Oriented Network Protocol) and SCLNP (Specific Connection-Less Network Protocol) are two older protocols for Packet Data Service. In the current version of the standard, PDP (Packet Data Protocol) is used instead.

3.2 TETRA Peripheral Equipment Interface

TETRA standard ETSI EN 300 392-5 defines a standard interface, PEI (Peripheral Equipment Interface), for connecting a peripheral data device to a TETRA mobile station.

Electrically, PEI it is a serial line connection, as defined by ITU-T standard V.24 (logical signals) and V.28 (electrical characteristics) [3], and EIA standard EIA232 (formerly RS232) [4]. The default character format is (8,N,1): 1 start bit, 8 data bits, no parity bit, 1 stop bit). Hence, the interface is a standard asynchronous serial line as found e.g. on personal computers. The default baud rate is 9600.

*AT commands (the default protocol). This is the industry standard method of communicating with and setting up a modem, originally defined by Hayes (a modem manufacturer). The AT commands set is modified and extended as necessary. SDS messages can be sent and received with corresponding AT commands. Other AT commands are defined for switch into Circuit Mode (transparent data connection), TNP1 or Packet Data mode, and mechanisms are defined to get back to the AT commands mode.

- TNP1 (TETRA Network Protocol Type I). The difference between AT commands and TNP1 is that TNP1 commands can be sent in parallel with ongoing packet data services whereas AT commands can only be sent in the command state.
- Packet Data.

Fig.2 shows protocol stacks that must be implemented in the peripheral device for various PEI protocols. As can be seen, TNP1 and Packet Data modes require IP and PPP protocols while AT commands (including SDS and Circuit Mode) need no additional protocols.

4 TETRA for SCADA

Fig.3 shows the block scheme of a system where TETRA is used by a SCADA system to transmit data between its supervision center and a Remote Terminal Unit.
not be directly connected together for the following reasons:

- A TETRA mobile station is initially in the AT commands mode and must be given some AT commands before sending any data. For the SDS service, data packets must be given as part of an appropriate AT command.
- SCADA data packets may be too long for TETRA (e.g., SDS messages have a maximum length of 2039 bits) and need to be fragmented into smaller packets before sending, then reassembled again upon reception.
- The SCADA serial line character format can be different and incompatible with that of TETRA PEI. This is in fact the case with our SCADA, which uses asynchronous serial communication with a special 16-bit data format.

Hence, a protocol converter is required, which controls the TETRA mobile station and reformats data packets as required. If TNP1 or Packet Data PEI protocol is used, IP and PPP protocols must be implemented in the converter, which is a relatively demanding task, requiring more complex and capable hardware and software. The AT commands protocol can be handled much more easily, and SDS is well suited for the efficient low-data-rate packet-data communication needed for SCADA.

Fig.4 shows the block scheme of the protocol converter. Since a simple TETRA protocol is used, the converter itself could also be made simple. It is built around a single-chip microcontroller 80C31, with a CPLD (Complex Programmable Logic Device) implementing an additional serial line, parallel inputs/outputs and auxiliary logic. The converter has three serial lines:

- TETRA PEI - for connecting to a TETRA mobile station. It uses the 80C31’s built-in UART (Universal Asynchronous Receiver-Transmitter).
- SCADA - for connecting to the SCADA system, supporting non-standard character format.
- monitor - an auxiliary serial line for test and debug purposes.

4 Conclusion

Data communication services of new professional cellular wireless communication systems like TETRA, are promising candidates for connecting large distributed industrial systems. TETRA is currently in experimental use in Slovenia. One of the prospective applications is to connect some of the remote stations of the Slovenian gas distribution system to the supervision center. However, the existing SCADA system does not support the use of TETRA mobile stations. A special protocol converter had to be designed to interconnect both systems, as described in this paper. The next steps will be to develop the necessary firmware for it, followed by laboratory and field testing of the whole system.

References: