TETRA for Data Communication in a Power Distribution System

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Abstract: Mobile radio communications are an indispensable part of communication networks in systems such as electric power distribution systems that cover large geographic areas and require maintenance and management of devices on remote locations where no other communication means are available. Besides the traditional voice communication, the new digital PMR systems also support various modes of data communication, including IP protocol. This offers new possibilities for remote data applications. In our paper, the possibilities of using a TETRA system for remote data applications will be described for the case of the electric power distribution company Elektro Ljubljana, d.d.

Key-Words: electric power distribution, remote metering, automated circuit breakers, PMR, TETRA

1 Introduction

Digital Professional Mobile Radio (PMR) systems are replacing existing analog PMR systems. Besides better voice services they offer additional data communication services, opening new possibilities for data applications. In this paper we analyze the possible use of the PMR system TETRA for data communication in an electric power distribution company. Its possible use for applications such as remote control and supervision of equipment and remote electric meter reading will be presented for the case of Elektro Ljubljana. Elektro Ljubljana (http://www.elektro-ljubljana.si/), with about 300.000 consumers, is the largest of five Slovenian electric power distribution companies, each serving a particular geographical region of Slovenia (Figure 1).

Fig. 1: Map of Slovenia and Elektro Ljubljana

2 Digital PMR systems

Wireless radio communications form an indispensable part of the communications infrastructure in organizations and enterprises that need to communicate with individuals or groups working in the field, and where other means of communication (especially fixed wired links) are neither suitable nor available. Public communication systems like the public mobile phone system GSM are only partially usable since they have not been designed for reliable operation in emergency situations. In such circumstances, when they would be most needed, they are likely to fail, partly due to simply being overloaded by public communication traffic (voice calls). For reliable professional use, special Professional Mobile Radio (PMR) systems have been developed. The existing analog variants are being superseded by new digital ones. Their important features encompass high reliability of operation, fast call setup (e.g. 0,3 s in the case of TETRA), secure communication with authentication and speech encryption, group calls and conversations, priority assignments and management for different classes of calls, including emergency calls with the highest priority, dispatcher support (typical connections are between a remote user and a dispatcher), direct mode of communication between mobile/handheld stations without a base station, independent local operation of a base station in case of main switch failure or inaccessibility, a mobile station working as a repeater to connect users at a location not directly covered by a base station signal, etc. Modern PMR systems also support data transmission including the IP protocol.

A number of different PMR systems have been developed in different parts of the world. Two systems have been developed (and are used) in Europe, TETRA and TETRAPOL [1, 2, 3, 4]. TETRA (TErrestrial Trunked RAdio system) has an advantage over TETRAPOL in that it is based on independent public ETSI standards (European Telecommunications Standards Institute, http://www.etsi.org) and is supported by a number of equipment manufacturers, while TETRAPOL has been developed by French company Matra with the equipment now being produced by EADS. Although TETRA is the more recent system (the first installation in 1997) it is much more widely used.

3 TETRA

3.1 Brief technical overview

A TETRA system consists of one or more switches, one or more dispatch centres, base stations on fixed locations with good radio signal coverage, and user terminals (handheld and mobile radio stations). The system can be connected with other communication systems like wired and wireless phone systems and data communication systems with IP protocol. Figure 2 depicts a simple TETRA system with a single switch and a single dispatch centre (such a system would meet the needs of a single organization on the territory of Slovenia).

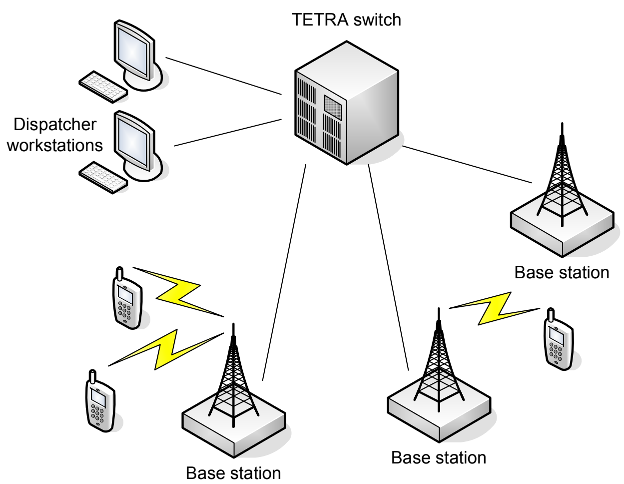

Fig. 2: A simple TETRA system

TETRA, like other modern digital PMR systems, supports virtual networks, enabling a number of independent users (organizations, enterprises) to share a common communication infrastructure (switches, base stations, etc.) while maintaining their communications virtually separated from each other. Infrastructure management is common and can be performed by a common body or an independent commercial TETRA network provider. In this way, the investment and maintenance expenses for each user are much reduced. The equipment is produced for existing PMR frequency bands, i.e. around 400 MHz for Europe and some other countries, and 800 MHz for USA and some other countries. Each RF channel is 25 kHz wide and carries four communication channels using Time Division Multiple Access (TDMA). One communication channel on each base station is reserved for use as a control channel (call setup, message transmission, etc.). The system uses Frequency Division Duplex (FDD), enabling full duplex communication.

3.2 Data transmission

TETRA supports different data communication modes that that can be used for a variety of data applications [5, 6, 7]. A communication channel can carry a circuit-switched link or packet data communication, normally with the IP communication protocol. Table 1 summarizes transmission speeds achievable over a single communication channel.

Table 1: TETRA data transmission speed (single channel)

Error protection level	Data rate [kb/s]
No protection	7,2
Normal	4,8
High	2,4

Up to 4 communication channels can be aggregated to achieve a correspondingly higher transmission speed (up to four times), but also with correspondingly higher consumption of communication resources (channels) and power in the mobile/handheld terminal. A TETRA terminal equipped with appropriate embedded software can be used as a WAP terminal, or as a modem for connecting a laptop computer or other data device to an IP network (e.g. Internet) over the TETRA network.

Another mode of data communication is SDS (Short Data Service), used for transmission of short status and user messages. This mode is useful for simple transfer of small quantities of data. Different types of user message exist for transferring either fixed-length 2-, 4- and 8-byte or variable length messages (up to around 255 bytes).

TETRA terminals have a standard interface for connecting user data equipment. This is (as in case of dial-up modems or GSM mobiles) an asynchronous serial line with AT command support.

3.3 Radio signal coverage

Compared to analog PMR systems operating at 160 MHz, the coverage of a TETRA system is smaller. This is due to the higher RF carrier frequency (400 MHz) and limited transmission power (average transmission power is 2,5 W max. for mobile stations and 0,25 W max. for handheld stations). Estimated coverage for Elektro Ljubljana from the 8 existing (analog) base station locations is shown in Figure 4. Better coverage would require a larger number of base station locations.

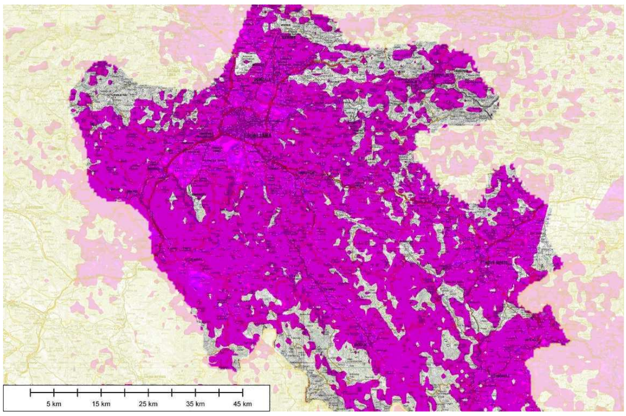

Fig. 4: TETRA radio signal coverage from existing locations

4 Data applications in electric power distribution

Besides standard voice applications (communication between the dispatchers and workers in the field), TETRA also provides data communication for the various data applications found in an electric power distribution system. These encompass:

- Remote control and supervision of circuit breakers and disconnectors.
- Remote control and supervision of power plants.
- Remote electricity meter reading.

4.1 Remote control and supervision of circuit breakers and disconnectors

A medium voltage power distribution network incorporates a large number of remote circuit breakers and disconnectors distributed over the whole network and located on power line poles. In a broader sense this problem is similar to remote control of power plants, however it deserves special treatment for the following special properties:

- It consists of a great number of control points distributed over the whole territory served by a particular electric distribution company.
- As a rule and in contrast to large power plants, there are no available communication lines (wired or optical) to these points.
- The required functionality of each control point is relatively simple, with only periodical communication and low data throughput, for which TETRA is a very suitable solution.

In the distribution network of Elektro Ljubljana there are currently 63 automated (remotely controlled) circuit breaker/disconnector points. Their locations are shown in Figures 5 and 6. In the future, automation of up to 200 remote circuit breaker/disconnector points is expected.

Currently, the public mobile phone system GSM is used for remote control and supervision, which constitutes a considerable problem regarding

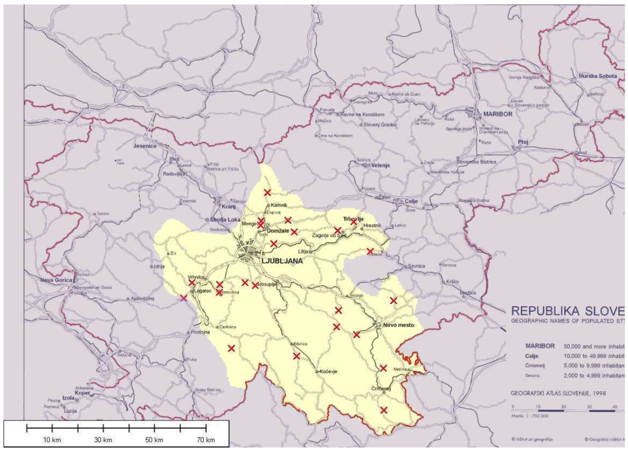

Fig. 5: Circuit breaker locations (Elektro Ljubljana)

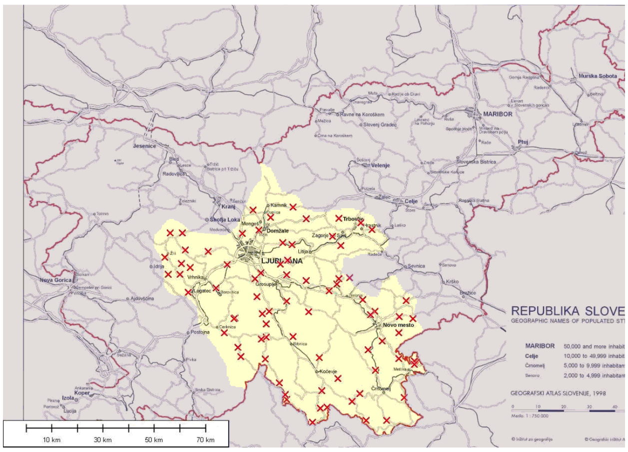

Fig. 6: Circuit disconnector locations (Elektro Ljubljana)

operational reliability. Remote data links are established only when data have to be transferred. The connection setup process in GSM is quite lengthy compared to that in TETRA and can not be neglected, especially compared to the time needed for the small amounts of data to be transferred, and causes delays in control and supervision.

TETRA would be a good solution for this application. The amount of transferred data in normal situations is low, with only two to four calls daily. Even in emergency situations one data channel per base station would be sufficient for this application. However, good radio signal coverage would be required, which means building an adequate number of base stations. Individual breaker/disconnector locations or smaller areas without direct base station coverage could be reached via intermediate TETRA terminals working as repeaters. Figure 7 shows the locations of existing automated breakers/disconnector and distribution substations, together with estimated radio coverage from 13 TETRA base stations.

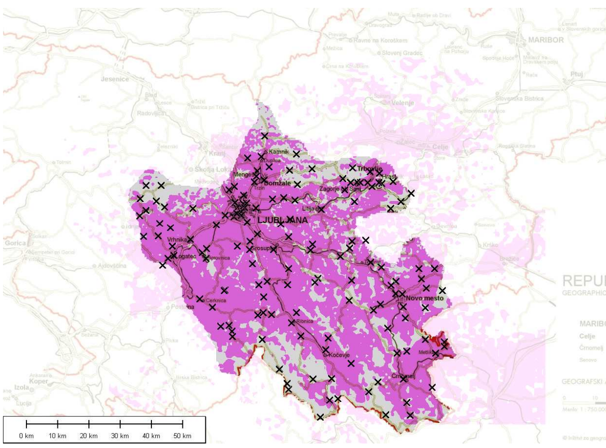

Fig. 7: Locations of power plants (automated breakers/disconnectors and distribution substations) and TETRA signal coverage

4.2 Remote control and supervision of power plants

An electric power distribution network consists of a large number of substations with electric power switch devices and transformers. They are mostly located close to bigger cities or large electric power consumers (industry) where fixed communication links are normally available for remote control and supervision. Here, TETRA could be used as a secondary (backup) system for emergency cases when the main wired communication network is damaged. In backup mode, the remote control and supervision system should be able to operate with the limited TETRA data transmission speeds (a few kb/s, see Table 1), which is substantially lower than those of optical or wired-line communication links.

4.3 Remote electricity meter reading

An important data application in electric energy distribution is remote electricity meter reading. The consumers can be divided into two groups:

- Large consumers (industrial/commercial). This is a relatively small group, but with a large power consumption. Elektro Ljubljana has currently around 3000 large consumers. Daily meter reading is required. Remote reading is already implemented. In more than half the cases (2000) it is done with wireless communication using the public GSM system.
- Household consumers. Only monthly reading is required, which is currently done manually, although there are some experiments with remote reading going on.

The implemented remote reading system based on the use of GSM is not without problems, nevertheless this is a suitable solution since the process is not time-critical and GSM provides good radio coverage of the whole territory.

TETRA could be used for remote metering of electricity consumption. In this way technical problems and expenses related to GSM would be avoided, assuming that no additional investment in TETRA would be required. However, the use of TETRA for this purpose involves certain difficulties. The main one is the large number of household customers (300.000 in the case of Elektro Ljubljana) and, with current prices of terminals, this would be expensive. Supporting such a large number of terminals by a TETRA switch would also be expensive and can even be technically questionable, depending on the particular manufacturer and its product, since TETRA systems are generally developed to be used as PMR systems for voice communication with a smaller number of terminals.

The monthly amount of transmitted data for a large consumer is about 500 kB. For 4000 consumers, this would mean about 15% of the average load of a single data channel. For a household consumer the amount of data is much smaller – only one reading per month – however the number of consumers is much larger and would constitute 38% of a single data channel capacity. Since the operation is not time critical, it could share data channels with the remote control and supervision of circuit breakers and disconnectors. An additional problem would be the non-uniform distribution of consumers, who are concentrated in urban areas, which would require additional investment in infrastructure. We can conclude that the TETRA system is not appropriate for a massive remote metering application due to the large number of terminals required. For household consumers it would be sensible to collect measurements at the transformer stations (around 4000 of them on territory served by Elektro Ljubljana) using other dedicated shorter range communication systems (wireless, power-line). From there on the measurements could be transferred over existing wired communication links, while TETRA would be used only in places where no other communication option would be available.

5 Conclusion

We investigated the possible use of the TETRA communication system for data transmission in electric power distribution systems, using the Elektro Ljubljana distribution company as an example.

TETRA is a modern digital PMR system. As the existing analog PMR systems are slowly becoming obsolete and analog technology is everywhere being replaced by digital, we can expect that the need to replace analog PMR with TETRA will grow in the near future. The necessary equipment is more expensive, but it also provides greater functionality for voice as well as data communications, including support for the standard IP protocol.

In the framework of an electric power distribution system, data communications can be used for various purposes like remote control of circuit breakers and disconnectors, control and supervision of power plants, and remote electric meter reading. Because of its limited capacity for communication channels, TETRA is suitable for use mostly in cases where other communication channels are not available.

It must be kept in mind that TETRA, due to its technical characteristics (higher RF carrier frequency, limited transmission power), requires a larger number of base stations compared to analog VHF PMR systems. Because of that and of the equipment complexity, investment in infrastructure is higher. The expenses can be much reduced if a number of users (organisations, companies) decide to build a common system, since TETRA supports virtual networks and hence independent sharing of its communication infrastructure.

References:

[1] J. Dunlop, D. Girma, J. Irvine, *Digital mobile communications and the TETRA system*, John Wiley & Sons, 1999.

[2] *TETRA: standard public safety trunked radio systems - assessment of technologies and markets for first responders radio*, Practel. Inc., November 2005, http://www.gii.co.jp/english/pra34284-safety-trunked.html

[3] TETRA Association, http://www.tetra-association.com/

[4] TETRAPOL Forum, TETRAPOL Users' Club http://www.tetrapol.com/

[5] I. Ozimek, G. Kandus, SCADA system using TETRA communication network, *Recent advances in computers, computing and communications*, WSEAS, 2002, pp. 164-166

[6] I. Ozimek, A. Hrovat, Concurrent POCSAG and TETRA paging, *WSEAS trans. commun.*, Vol. 5, No. 1, 2005, pp. 31-36

[7] G. Kandus, A. Hrovat, I. Ozimek, M. Smolnikar, T. Ban-Zlatev, Telemetry services over TETRA network for disaster management, *WSEAS trans. commun.*, 2007, vol. 6, no. 3, str. 451-456.