MISSION CRITICAL ICT

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Critical Review
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Abstract: In this paper, three technologies intended to be implemented in Private Mobile Radio systems are analyzed and compared: TETRA (Terrestrial Trunked Radio), LTE (Long Term Evolution) and DMR (Digital Mobile Radio). Characteristics of these networks are collected and compared in one SWOT table. Based on this analysis, appropriate recommendations are made, which should be taken into account when choosing a specific solution for specific uses in Critical Communications systems.

Keywords: DMR, ICT, TETRA.

INTRODUCTION

Critical mission is a basic function that is extremely important for the functioning of the organization. Depending on the scope of activity of the organization, the use of the term critical mission is changing. Here, we will imply that the critical mission relates to PPDR (Public Protection Disaster Relief) organizations. Mission critical communications imply that PPDRs have technical communications systems in place, that allow for safe and reliable communication during operations. When planning such systems, special attention is paid to the reliability of the system. Statistics show that 85% of radio sessions is exposed to concentrated disturbances [5]. The risks that could lead to communication interruptions during operations must be minimized or, if possible, avoided altogether.

MISSION CRITICAL COMMUNICATIONS

In the relatively recent period, there has been a global technological shift from analogue to digital systems, which, in terms of public safety, is most reflected in the adoption of TETRA standards [2] and the introduction of TETRA systems in operational use in most European countries. Since the introduction of the TETRA system is a costly and time-consuming process, other standards have been specified, primarily intended for business users, such as DMR (Digital Mobile Radio) and dPMR (Digital Private Mobile Radio). As TETRA systems provided quality and secure communication, the development of commercial mobile technology did not meet the needs of public services. However, the need to transmit large amounts of data, primarily video streaming in real time, has led to the adaptation of both TETRA and mobile telephony standards.

The TCCA (TETRA and Critical Communications Association) has embraced a scenario whereby public security services are moving from voice-oriented to data-oriented communications, which covers a much broader aspect. Also, TCCA identified a lack of support for modern applications that produce and transmit large amounts of data, as the biggest limitation of the TETRA system and selected LTE as the technology for broadband mobile networks for mission critical and business critical communications. Future public safety networks must maintain the same level of management, security and high availability as existing public safety networks does, but they must additionally be capable of enabling the use of advanced applications which are present in commercial networks today [3].

The mobile radio communications system must meet the key requirements in order to be used for mission critical communications: Reliability (High availability of system infrastructure and minimums of service availability when infrastructure is unavailable); Centralization-decentralization of operations (central dispatch point for customer management and possibility of DMO (Direct Mode Operation) - operations without centralized control or without infrastructure); Different types of calls (individual call, group call - for all members of a specific group, general call - for users outside the group); Making a call (minimum time for making a call, PTT (Push To Talk) function, Receive calls immediately); Communication security (User authentication, Air interface encryption); Call priorities (Divide users by priority level, Assigning priority to emergency-alarm calls); Transmission of text data (the ability to send and receive text messages, ability to implement GPS location); Packet data transmission (the ability to transmit and share video signals, ability to work with the business information system) [1], [9].

In the rest of the paper, three technologies intended to be implemented in PMR (Private Mobile Radio) systems are described and compared:

1. TETRA - the most widely accepted technology for PMR in public services,

2. LTE - the latest mobile radio standard, initially intended for mobile operators, but it is supplemented by requirements for PMR use

3. DMR - PMR standard, newer than TETRA standard, intended for less demanding PMR users. DMR is a mission-critical, lower-cost variant most commonly used by regional rather than national services.

TETRA (Terrestrial Trunked Radio)

TETRA is a telecommunication standard for private mobile radio systems, developed by ETSI (European Telecommunications Standards Institute).

TETRA is a system designed for services that require the highest level of communications security and system reliability, whose efficiency and cost-effectiveness are reflected in the ability to share infrastructure between multiple users while maintaining privacy and security. Virtual networks within a single TETRA network enable each organization to use the system independently of others. Implementing the TETRA system for several different services lowers the cost of implementation because all services share the same infrastructure. TETRA is a technology that achieves superior communications security through encryption of voice communication, data transmission, signaling data and user identities. TETRA system [2] is primarily intended for the transmission of voice communications, although it can also be used for data transmission (short text messages and "slow pictures"). Tetra system architecture is shown in Figure 1.

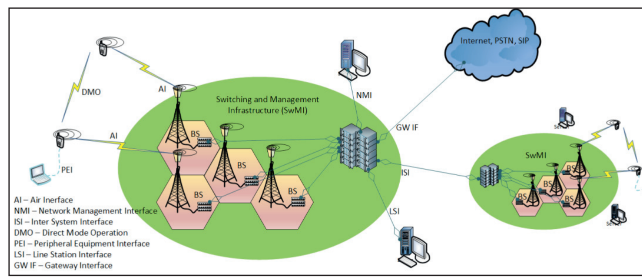

Figure 1. *Tetra system*[1]

For data transmission, the basic data rate per time slot is 7.2 kbps, but if all four slots are used it is possible to achieve a data rate of 28.8 kbps. When a time slot is used for packet data, no voice call can be made through that slot.

TETRA 2 - TEDS (TETRA Enhanced Data Service) standard offers an improvement in data transmission. This increase in speed also requires an increase in the bandwidth used. Thus, at a channel width of 150 kHz, a transmission speed of about 500 kbps is possible in best case.

The basic mode of operation of the system is the tranking mode. Tranking is a term used in telecommunications to refer to a situation where multiple users are sharing the same set of frequencies, rather than each user using only his own frequency. User devices exchange radio messages with the base station. The base station is connected to the switch. The base station authenticates the terminal device and only devices that have been approved in advance can log on to the system. All communication between the user devices is done through SCN (Switching Control Node).

[1] ETR 300-1, May 1997

In case of unavailability of infrastructure, other modes of operation are possible to provide minimum service:

- **mobile repeater mode** - mobile terminal device can play the role of a radio repeater - increase signal coverage. In this case, call establishment is done through SCN,
- **DMO - mode** when communication is performed between two or more terminal devices without the mediation of SCN,
- **Repeater mode** - when the base station does not connect to the SCN, it acts as a classic radio repeater for devices that are logged in and authenticated.

There are two prevalent models of TETRA system implementation: the private network and the establishment of TETRA operators.

LTE (LONG-TERM EVOLUTION)

LTE represents the fourth generation of wireless communication standards, i.e. continued development of GSM / EDGE (second generation) and UMTS / HSPA (third generation) network technologies. The main advantage over previous generations is the mobile broadband capacity, ie. multiple increase in data rate.

GSM technologies are primarily intended for mass commercial telephone services. As such, they were not intended to satisfy the communications requirements of mission critical implementations.

It must be taken into account that in parallel with the development of GSM, TETRA has been developed as a system for critical communications. However, commercial standards are evolving much faster than TETRA, which is primarily intended for PPDR, and as a result, critical communications requirements have been incorporated into commercial standards since 3GPP (The 3rd Generation Partnership Project) issue 12. Current issues of the standard, as specified in the 3GPP Specification Release version matrix[2], supports critical communications requirements [7], [8]: ProSe - Proximity Services (DMO), GSCE - Group System Communication Enablers, IOPS - Isolated E-UTRAN Operation for public safety, MCPTT - Mission Critical Push to Talk.

ProSe - Proximity Services (DMO) service is an upgrade of the LTE standard that should allow communication between two terminal devices directly, i.e. without LTE infrastructure participation or via eNB (E-UTRAN Node B), but without LTE core network participation. This service is the counterpart to the DMO and to the repeater mode of operation of the TETRA terminal and base station. The aim is to provide communication between terminal devices also in areas that are not covered by the LTE radio network for whatever reason or when there is a radio signal with an eNB, but the eNB does not have connection to the network core. This method is primarily used to transmit voice communications.

GSCE - Group System Communication Enablers is a service that supports group calling, the use of dispatch consoles, and streaming audio and video signals to multiple devices using a single downlink data stream.

IOPS - Isolated operations for Public Safety - represents the ability of terminal devices to operate without network infrastructure or over isolated eNBs. This functionality is intended for PPDR organisations.

MCPTT - Mission Critical Pust to Talk service over LTE is an application layer service designed to extend the architecture of the LTE system. It provides PTT functionality over LTE infrastructure and DMO communications. The extension over the TETRA system is reflected in the possibility of duplex communication.

The LTE access network is a base station network - eNB, which has a flat architecture because, unlike earlier generations, it does not have a central intelligent controller [4]. The flat architecture allows to reduce delays in network response, which is positive for applications that require high data rates. LTE elements are highly optimized and very complex with the aim of making the most of the available radio spectrum. Basic LTE network infrastructure is showed in Figure 2.

LTE technology enables an optimum bandwidth of 2 x 20 MHz to achieve a downlink speed of 300 Mbps, or downlink speeds of 75 Mbps are possible for reduced allocation of the 2 x 5 MHz spectrum. These values are much larger than the TEDS and allow for seamless video sharing.

The implementation of the LTE network for public security is observed from three aspects:

1. Technology aspect - LTE standardization organization has adopted a version of the standard that

[2] https://www.3gpp.org/DynaReport/SpecReleaseMatrix.htm

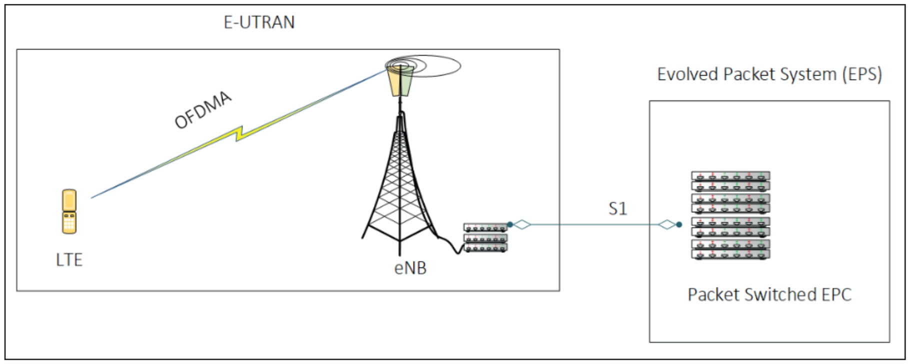

Figure 2. *LTE network Architecture*

is tailored to the requirements of communications of critical situations,

2. The network aspect is reflected through various ways of realizing business models,

3. Radio frequency spectrum - a prerequisite for implementing the system is to regulate the use of the RF spectrum both nationally and globally.

From a network point of view, the system of critical communications can be implemented by utilizing the resources of commercial telecom operators to a greater or lesser extent. It is also possible to build a private LTE network, but in this case the problem of RF spectrum allocation arises. Therefore, there are three models [7]:

1**. Private LTE network** - a special system established for the needs of the public security service. There are also two implementation principles for implementing a private LTE network:

a. The network is owned and operated by the organization that uses it,

b. The network is owned by another organization in charge of resource management, and public safety is the beneficiary.

2. **Commercial LTE Network** - Resources for public security are reserved within commercial networks. There are two models here too:

a. SLA - Service Level Agreement, when a subscription agreement is reached with commercial operators that perform customer management,

b. Virtual Private Operator - when the resources of commercial operators are used to organize own system in which the organization can manage capacity and customers.

3. **Hybrid solutions** - a combination of the previous two, especially in terms of infrastructure use.

DMR (Digital Mobile Radio)

DMR is a telecommunications standard for private mobile radio (PMR) systems, developed by ETSI (European Telecommunications Standards Institute)[3]. In relation to TETRA, this is a newer standard and the aim of the introduction was to reduce the complexity of the system as is the case with the TETRA standard. It is intended for use in three Tier: Tier I, Tier II and Tier III. Tier I is intended for unlicensed use, Tier II is intended for licensed use in a conventional network and Tier III is intended for licensed users in Trunk mode.

Data transmission involves the ability to exchange text and control messages, but packet data transmission has a modest capacity that is lower than the capabilities of the TETRA system but is sufficient to transmit telemetry data.

DMRs can also operate in analogue mode and are compatible with existing analog devices. However, not all digital mode functionalities are available when operating in analogue mode.

The DMR Tier II system consists of: repeaters, dispatch stations and terminal equipment, as Figure 3 shows. Device manufacturers on the market offer devices that can be upgraded from a DMR Tier II to a Tier III, with software upgrade, without the need for hardware changes.

Traditionally, repeaters are not connected and it is not possible to communicate between two users who receive signals from different repeaters. However, the advancement of technology has brought novelty to such systems as well. These news are reflected in the connection of the repeater via internet protocol. In this way, it is possible for users to communicate regardless of distance.

[3] ETSI TS 102 361 (1-4)

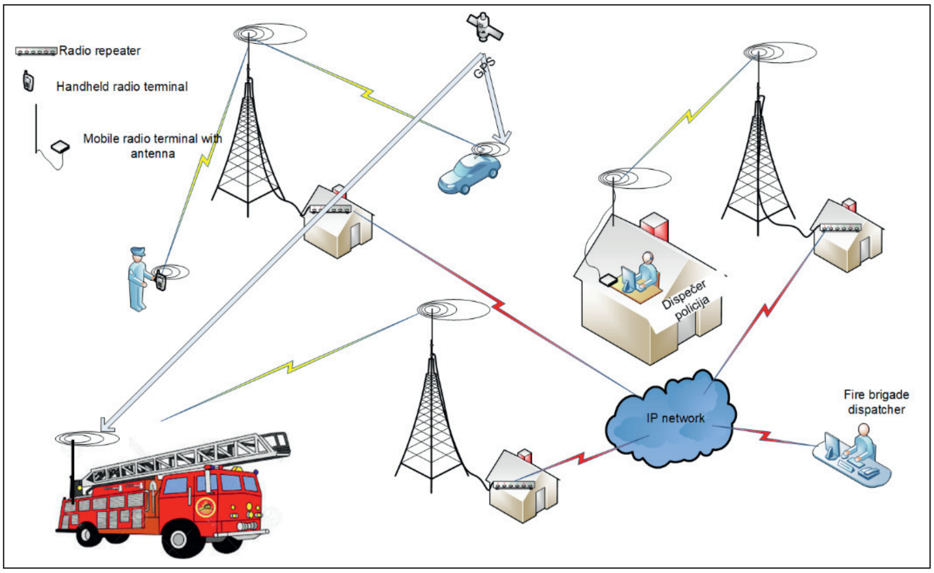

Figure 3. *DMR II system Architecture*

The DMR Tier III system has a trunking architecture. Repeaters have the role of base stations, and with respect to the DMR Tier II, all parts of the system must be connected into a single entity, the control of which uses a central switch. Connecting the system to one unit makes it easier to manage users, i.e. assigning rights to user devices.

Comparing

TETRA, as the most recognized technology for use in public safety services, has the highest number of implementations in public services worldwide. LTE with TETRA and DMR with TETRA technology are most commonly compared in the professional literature. Direct comparisons of DMR with LTE have not been made, primarily because DMR II is not a trunking technology and therefore has limitations in the requirements for mission critical systems. DMR III systems are just beginning to be implemented and are mostly implemented in organizations that do not have a budget sufficient for the TETRA system.

Tables 3, 4, 5 and 6 present the SWOT analysis of DMR, TETRA and LTE technologies respectively . SWOT analysis is one of the management tools used when making some strategic decisions related to the organization.

Table 3. *SWOT Analysis - Streinghts*

DMR	TETRA	LTE
Open standard	Open standard	Open standard
Supports analog devices	Device and infrastructure compatibility	Very high data rates
Low spectrum requirements	Low spectrum requirements	Suitable for modern applications
VHF Possibility to work in VHF range	Full duplex	Full duplex
Territory coverage by signal	Communication protection	Interoperability with other communication systems
Cost of implementation	Evidence of technology - a large number of implementations	Supported by manufacturers of commercial systems

Table 4. *SWOT Analysis – Weaknesses*

DMR	TETRA	LTE
DMR Tier II is not intended for critical communications	Cost of implementation	Critical communication systems have not yet come to life
Insufficient interoperability of devices from different manufacturers	Territory coverage by signal	Territory coverage by signal
Low data transfer capacity	Low data transfer capacity	

Table 5. *SWOT Analysis – Opportunities*

DMR	TETRA	LTE
Particularly suitable for rural areas	A standard that is still evolving	A standard for developing mobile communications, including mission critical communications
Ease of implementation	Proven high reliability	

Table 6. *SWOT Analysis – Threats*

DMR	TETRA	LTE
A standard designed to fit into the ranges traditionally intended for analog PMR systems, thereby also overcoming the limitations of those data transmission ranges	Implementation complexity	Lack of available frequency spectrum in recommended areas
High availability of the system is still not ensured	The emergence of quality PMR solutions, above all DMR Tier III	

Based on the SWOT analysis, we can conclude that there is no ideal solution. What can be said with certainty is that the future of communications belongs to LTE technology, so when the system is built from the beginning the decisions are most often for LTE technology. Countries that already have a TETRA system in place throughout the territory resort to hybrid solutions, where existing infrastructure is retained prior to voice communications. LTE is used to transmit video signals.

When deciding on a technology choice, we can choose some of the crucial factors to choose from, such as the cost of implementation, the time it takes to bring the system to operational use, and the need to transfer large amounts of data. In this case we will choose:

- DMR system - if the price of the system would be a crucial factor,
- TETRA - if there is an adequate budget, and time to provide the frequency spectrum is short,
- LTE - if the system must support the transmission of lots of data.

Conclusion

TETRA is the most recognized standard for radio communications in public safety organizations. It enables very efficient customer management, but system administrators need to be properly trained. Building a system requires time and considerable material resources, and still, new and expensive system will not be able to transmit video. In this sense, financial and technical justification of implementing TETRA as green field is questionable.

LTE and incoming 5G [6] technologies are the future of radio communications. Implementing a private LTE system is expensive and can be hampered by the regulator's inability to provide adequate frequency bandwidth. Implementation in collaboration with commercial operators carries its security risks, that can be kept under control by an adequate organization of the cooperation. It is the only system that allows the transmission and sharing of video content.

Finally, based on the research and SWOT analisys which is conducted in this paper, we can say that DMR technology is a very convenient solution if closed networks is the main goal, because of the cost, the time of implementation, the training of the administrators, and because it offers same functionalities to users as other digital technologies do. By encrypting the air interface, communication security is also achieved.

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