INTL JOURNAL OF ELECTRONICS AND TELECOMMUNICATIONS, 2020, VOL. 66, NO. 1, PP. 231-236
Manuscript received November 15, 2019; revised January, 2020. DOI: 10.24425/ijet.2020.131868

Radio Dispatching Communications During a Mass Event - A Case Studies of the "Lednica 2000" Youth Meetings

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***Abstract*—In paper we present a case study of the radio dispatching communications for providing the voice service during mass events of the "Lednica 2000" Youth Meetings. The presentation is supported by over 20-year experience in organization of this event every year. We also describe a FM radio system deployed during this meeting for broadcasting the English translation.**

***Keywords*—wireless communication, dispatching network, mass event, energy sector, radio broadcasting**

I. Introduction

WIRELESS communications especially in area of voice services is still a key element of the Public Protection and Disaster Relief (PPDR) domain during routine day-to-day activities, major events (e.g. mass events) and major incidents or disasters. In such cases public mobile networks can be out of order due to destructions or fail due to the congestion that consumes whole capacity of resources in a location or even neighboring ones within a location area or a sub-network of sites. That is why and in order to increase the security of information exchanged by First Responder (FR) entities the demand is still observed to install wireless dispatching systems, including trunking ones. On the other hand they will be replaced in the near future by systems based on technologies of the 3rd Generation Partnership Project (3GPP) including 4G and 5G standards to provide voice services with guarantee low latency and low call set-up time as well as broadband data services that are required more and more often by PPDR organizations. Such an approach will be possible because new Quality of Service Class Identifiers (QCI) will be introduced [1] for which quality parameters are even twice more strict as for current Voice over Long Term Evolution (VoLTE) services. It will allow to deploy Mission Critical Push-To-Talk (MCPTT) services in PPDR networks and Push-To-X ones that will be also available for Device to Device (D2D) communications using the multicast transmission.

An example of events that need and use radio communications on the large scale is the "Lednica 2000" Youth Meeting that is organized every year on the turn of May and June by "Lednica 2000" Community operating at the Dominican Monastery in Poznań. These meetings have over 20 year history. Due to an expansive area (ca. 2.4 km^2) where they are held, ongoing dynamics of activities and need to ensure safety for the mass event with over 150 thousand participants the radio communications is an important element because it allows swimmingly proceeding according to the planned script of the whole event and ensuring continuously flow of information to support decisions taken by the organizer. Operation continuity and reliability of the deployed radio network result not only from current needs of the organizer and from lawful regulations related to mass events but operational requirements are also defined taking into account incidents that may occur and be amplified by unpredictable collective intelligence. Moreover, Electro-Magnetic Compatibility (EMC) and Inter-Modulation Distortions (IMD) are considered that may result from other radio systems operating on site and used by other entities that are present during the meeting, e.g. by radio and television broadcasters, personnel of the sound system with many wireless microphones, scout organizations that have own radio terminals, PPDR entities as well as participants who use sometimes PMR446 (Private Mobile Radio) terminals.

The paper is organized in the following manner. Section II extends the introduction written in Section I and presents a short history of requirements related to the radio communication means used during the Youth Meetings. A way how wireless communications is organized is described in Section III. Results of measurement of the traffic intensity are shown in Section IV. In Section V other examples are described where the Digital Mobile Radio (DMR) system is used. Conclusions are presented in Section VI.

II. Experiences Gained during Organization of the "Lednica 2000" Youth Meetings

A need to ensure an efficient and secure radio communications has been raised since the beginning when the "Lednica 2000" Youth Meetings started to be organized. During the 1st Youth Meeting in 1997 there was a chance that the Pope John Paul II would land on site travelling on the board of a helicopter to Gniezno located in the vicinity. It needed to prepare a landing pad and to cooperate with PPDR organizations. In subsequent years the increasing number of participants, different forms of the services said during the meeting, new types of interactions with the youth as well as diversity of processions when many people demonstrate their talents (including air shows with airplanes, motor gliders or parachuters) have required a radio communication network of

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high capacity and reliability. A problem of the scalability is of less importance because a number of radio terminals to provide the voice communications for services acting as groups involved in different specific tasks during the meeting is known by the organizer in advance.

III. Communication Network During "Lednica 2000" Youth Meetings

A radio communication network located in Pola Lednickie consists of radio terminals and repeaters that work in analog or digital mode offered by the Digital Mobile Radio (DMR) standard by Motorola because this standard is also used for the crisis management system and by National Medical Emergency System (NMES) (PRM – Państwowe Ratownictwo Medyczne) at a voivodeship level in the Greater Poland. The network is based on the Mototrbo professional two-way system that can work in different configurations: direct mode, single site, conventional networking or (dynamic or full) trunking. The established network is used to set up individual (only in digital mode) and group calls for the task services that are responsible for organization of the meeting. The services in charge are following:

1. operations staff – main coordinators of the meeting,
2. security service – security coordinator and personnel involved in protection of the place where main activities are hold,
3. medic service – medical service that encompasses medical coordinator, main hospital and field ones as well as pharmacy center,
4. traffic service – management of the vehicle traffic at enter gates (check points) to the area of the meeting,
5. waste disposal service – maintenance of cleanliness on the spot,
6. liturgy service – support of the celebration and processions,
7. communication service – supervision of the radio communication network,
8. news office – broadcast of audio and video contents on the spot and via Internet.

There two modes in the wireless communication network deployed in the area of the meeting:

- Direct Mode Operation (DMO) – terminal to terminal,
- repeater that works as a single site.

Majority of the task services is based on DMO. The repeater mode is used by the traffic service because it has furthermost posts situated even 2.2 km from the main location of the meeting. Using the repeater equipped with duplexer and omni-directional antenna installed on a roof of Center of John Paul II at 11 m AGL (Above Ground Level) it is possible to provide good quality communications at that distance though the transmit power is only 1 W. Following parameters are applicable (150 MHz band):

- transmitter power: 1 W $\hat{=}$ +30 dBm,
- effective antenna gain: +0.5 dBi (including cable loss),
- EIRP level: +30.5 dBm (1.1 W),
- hand held terminal dynamic sensitivity: –110 dBm,
- standard deviation of the shadowing - σ - for environment: 8 dB, location probability: 0.95 → fading margin: 13.2 dB,
- terminal antenna effective gain (including body loss): –8 dBi,
- minimal signal level as coverage criterion: –89 dBm,
- signal path loss allowed: +30.5 – (–88) = 118.5 dB.

Such result would theoretically lead to quite long coverage distance, it is although radically shorten by the trees surrounding the place of operation. Still, the coverage is very good even inside the building or in the cars while operating with the hand held terminals.

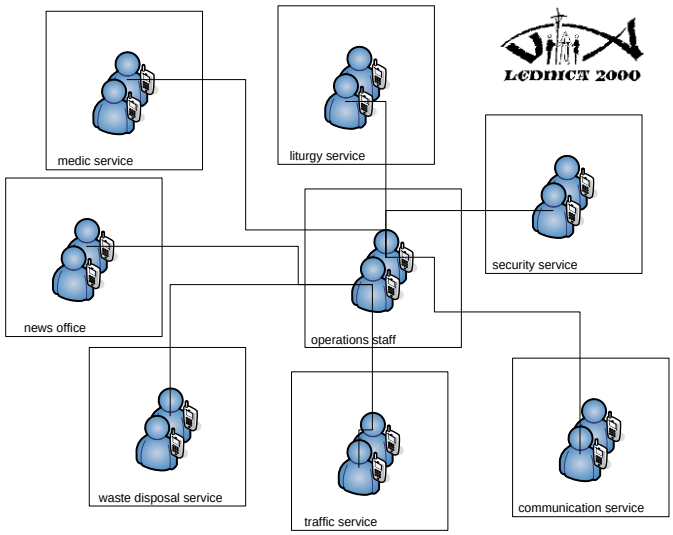

Fig. 1. Task services involved in the organization of the "Lednica 2000" Youth Meetings

Each task service has a few or several radio handy terminals that are programmed to work in groups created in separate radio channels (or a pair of channels for the repeater mode). For radio terminals working in the digital mode the allocation of the timeslot in the TDMA (Time Division Multiple Access) frame of the DMR standard is done dynamically, except communications for the operations staff whose terminals have one slot permanently assigned with possibility of its pre-emption.

The architecture of the radio communication network is shown in Fig. 2. The dispatching system ConSEL by AKSEL allows for direct connection with a network of repeaters. A computer of the dispatching consol is equipped with a LTE (Long Term Evolution) modem that enables connecting with Internet via a commercial mobile network. Using these two transit networks a ciphered Virtual Private Network (VPN) is established to a point of presence (PoP) where a gateway to sub-networks of the crisis management system and NMES is located. Due to it the communication service has connections to Voivodeship (= Regional) Crisis Management Center (VCMC) and two NMES dispatching centers in Konin and Poznań that collaborate with Public-Safety Answering Points (PSAP), police command centers and fire brigade command centers. It allows communicating with ambulances and Helicopter Emergency Medical Service (HEMS).

The ConSEL application is capable to emulate the radio terminal and to set individual and group calls up with pre-defined or manual selection of the timeslot in the DMR frame (*Fig. 3*). The ConSEL system allows managing users by identification of the radio terminals and visualization of their location on the map using the Automatic Vehicle Location (AVL) service. The location information can be displayed in different Graphic Information System (GIS) services like Google Earth, Emapa or raster maps.

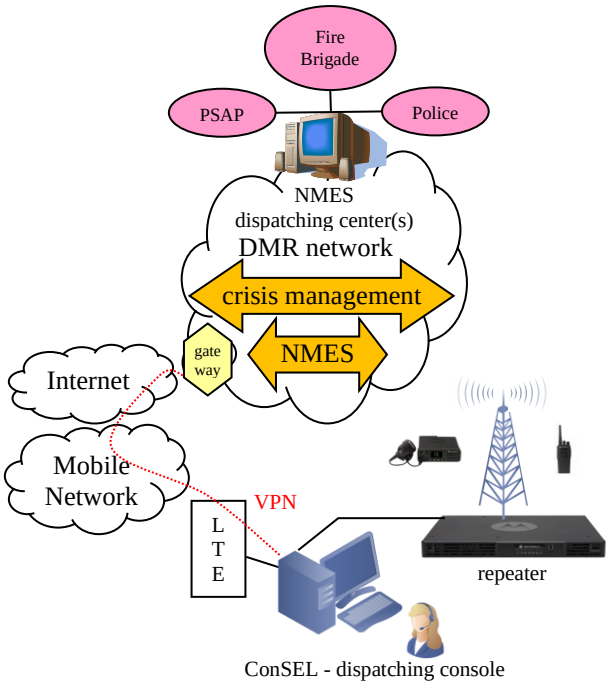

Fig. 2. Architecture of a DMR network where a ConSEL dispatching console is used

A dispatcher can also record voice communications and store Short Data Service (SDS) contents. This function also allows re-playing whole or parts of the voice talk and restore sent SDS messages. The application ensured improved ergonomics and quality of dispatcher's work. The system can be also used in a smartphone as ConSEL Mobile application to enable mobility to the dispatcher. Using the ConSEL platform during the meeting it is possible to integrate all task services in one dispatching console and easily establish connections between the dispatcher and users.

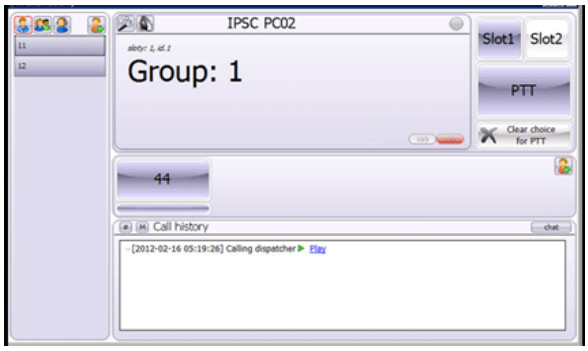

Fig. 3. Radio panel of a ConSEL dispatching console

In order to increase resilience of the radio communication network, a special vehicle is provided by the YAGI-FRYSKA company during the meeting. A van is equipped with a set of omni-directional antennas and Uninterruptible Power Supply (UPS) based on Lithium Iron Phosphate (Li-FePO) batteries that can be charged from photovoltaic solar panels installed on a roof of the vehicle. The radio equipment deployed on site can be powered from the UPS using a pure sine wave power converter. The power supply of the radio communication services can be guaranteed during the meeting even if a black-out occurs.

Hospitals and pharmacy center use fixed radio terminals by Radmor. They are equipped with UPS based on one Absorbent Glass Mat (AGM) battery. The repeater has also its UPS. Moreover, a dedicated encrypted digital communication channel is established among coordination chief, medical coordinator and the police.

In *Fig. 4* an estimation of the radio coverage is presented for a repeater with omni-directional antenna that has the gain of +1 dBi and is installed on the roof of Center of John Paul II. A single repeater allows providing the good coverage of whole area of the meeting. The transmission was based on VHF band: 147.85 MHz (RX) and 152.42 MHz (TX). The results were prepared using Radio Mobile application [2].

To ensure the reliable flow of information between task services the communication center is established during the meeting where the communication service makes the radio listening watch of all communication channels used by the organizer, scouts and HEMS. It allows receiving a message from one group and forward it to another group. Such a forwarding is much quicker than manual selection of a right communication channel in the terminal by a user. For the radio listening at least three fixed terminals (two analog and one digital) working in a scanning mode are used. These terminals have also UPSes. The communication center has access to Internet via the mobile network (Fig. 2) or WiFi Access Point (AP) installed in the news office located nearby that has a fixed Internet access over Public Switch Telephony Network (PSTN). Moreover the communication service can use the voice service over mobile networks and PSTN. The latter constitutes a back-up of the communication means. Services over PSTN are provided by Orange operator using an ISDN (Integrated Service Digital Network) concentrator installed on the spot. It is connected to PSTN with a few E1 links that are used mainly for IP (Internet Protocol) transmissions.

During the "Lednica 2000" Youth Meetings a broadcasting transmitter for the FM (Frequency Modulation) radio has also worked for a few years. It was used for simultaneous translation into English of contents spoken during the event for needs of foreign participants. FM receivers integrated with mobile phones were sufficient to listen to the broadcast. The transmitter was installed in Center of John Paul II and the antenna was mounted on its roof. Input audio signal to the transmitter was taken from a main audio mixer of the sound system. This signal was transmitted from a tent of the acoustic team located at the foot of the Fish-shaped Gate hill (about 200 m from the center) using an FM-modulated analog radiolink that worked in 2.4 GHz band.

IV. Analyses of Traffic on the Basis of Voice Connections

Using the ConSEL application by AKSEL [3] we analyzed traffic statistics for voice connections set up during the meeting in 2018 when about 50 radio terminals were used. For 13 hours when the network worked 2572 connections were established.

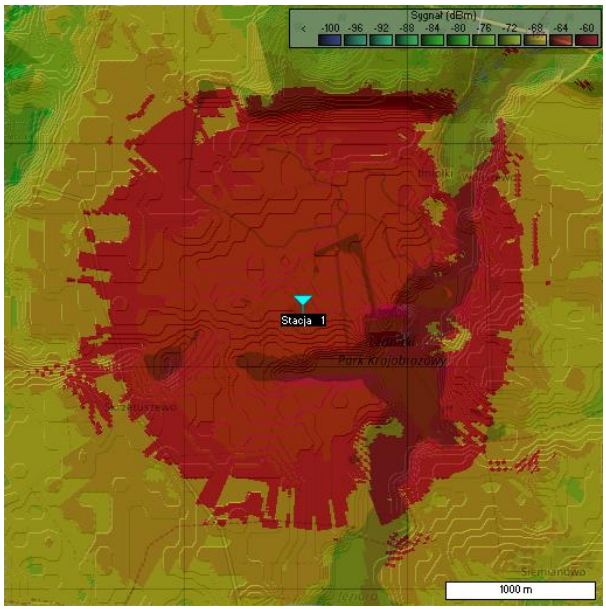

Fig. 4. Radio coverage of the repeater installed on the roof of Center of John Paul II

Looking into the collected records the Average Call Duration (ACD) was 10 s (Standard Deviation (SD) was 9 s; the shortest call was 1 s long and the longest one lasted 173 s). In a period of Busy Hour Call Attempts (BHCA) there was the call traffic of about 1.29 Erl (*Fig. 5*). The 1st timeslot of the DMR frame was occupied by 51 per cent of calls. The majority of calls was group calls (99 per cent). The request rate was six calls per minute.

The traffic intensity in the period ① is correlated with the preparation to the meeting. At 17 to 19 there was a radio silence because the President of the Republic of Poland was present. It is shown in the period ②. In the period ③ the main part of the meeting was proceeded. An increase of the traffic intensity in the period ④ resulted from a procedure of the meeting closure that was supported by Voluntary Fire Brigades.

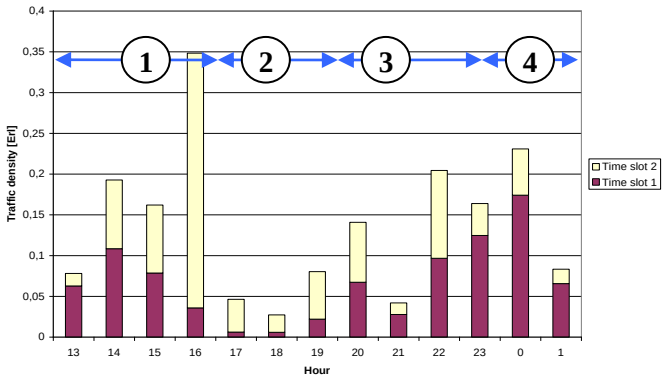

Fig. 5. Distribution of the traffic intensity during the meeting

V. Examples of Radio Dispatching Networks Based on DMR Standards by Motorola

In Poland there are two Wireless Wide Area Networks based on the Mototrbo system by Motorola. They are located in two voivodeships - wielkopolskie and łódzkie. The former has 35 districts (powiat) and the latter has 14 districts.

The network in wielkopolskie voivodeship has over 100 repeaters and is used for:

- crisis management system including the control of alarm sirens across the voivodeship,
- NMES.

In 2017 there were 200 fixed terminals, 220 vehicle-mounted mobile terminals and 450 handheld terminals [5].

Each system of above utilities has its own set of repeaters. In a typical installation of the site two repeaters are co-located and each utility operates one of them. This approach allows that the height infrastructure (masts and poles) and the transmission IP backhaul network are the same for both users. The backhaul network is based on wireline or wireless links. Each site has at least two links to ensure the redundancy using Ethernet cable link, Point-to-Point radio link or mobile Internet transmission. Sites are connected with encrypted VPNs.

In the backhaul network routers by DrayTek are used. They have two GigE ports for Wide Area Network (WAN) and two USB (Universal Serial Bus) ports for mobile stick modems. That is why three links in a configuration of the backup WAN can be established in areas of high risk. Moreover, it is possible to set up the high availability for a set of routers, bandwidth management as well as Virtual Local Area Networks (VLAN) including SSL (Secure Sockets Layer) VLANs [4]. The router has a firewall and a function of Content Security Management (CSM).

Each repeater has an UPS of minimum 120 Ah capacity from Lithium Iron Yttrium Phosphate LiFeYPO4 cells to ensure at least 5 day power back-up. Alternatively a hybrid system of the battery charging is applied based on photovoltaic panels and wind turbines. Some sites are deployed in the three-sector configuration in order to improve the coverage and ensure directionally separation of repeaters to avoid risk of interferences from e.g. radio networks in neighboring voivodeships. The sector antenna has been designed by Helix company specially for this application. The construction of the antenna is welded. The antenna system works in two bands of 148 MHz and 169 MHz.

To decrease the cost of the repeater installation a duplexer uses at least 500 kHz frequency separation. The Mototrbo system works in Capacity Plus mode that provides services using a technique of the dynamic trunking (it is not a full trunking of Tier III). When using this technique only repeaters that communicate with terminals within a talk group are involved. It allows saving communication resources (i.e. timeslots in frequency channels) and finally increasing the network capacity. However, the standby time of the terminal is 45 to 60 minutes shorter as compared to IP Site Connect mode.

There are five sub-networks in the voivodeship (Fig. 6) that are geographically separated around the district towns (Piła, Poznań, Konin, Kalisz and Leszno) [6] in order to meet system limitations (maximum 15 sites per subnetwork) and ensure a coverage across whole voivodeship. The whole network is monitored and controlled remotely using a dedicated application that provides diagnostic and management functions for both repeaters and backhaul links. Alarm sirens are

controlled via this DMR network in many cities using digitexCZK/IP warning system provided by Digitex company. The control servers are located in Poznań, Kalisz, Czarnków, Rawicz, Wągrowiec and Złotów. Communication with HEMS is still based on the analog transmission due to EMC conformity of the helicopters. The ConSEL application is used in dispatching centers of NMES and in VCMC. The ConSEL system in version 4.0 has the following features:

- support of the voice interface,
- support of the data interface,
- voice and SDS recorder,
- diagnostic of repeaters that is based on Repeater Diagnostic and Control (RDAC) tool,
- indoor localization using Bluetooth 4.0 beacons established with Mototrbo terminals (DP4xx1e and DP3661e),
- mobile consol installed on a mobile device with Android operating system.

Fig. 6. Network of DMR repeaters for crisis management and in wielkopolskie voivodeship

In łódzkie voivodeship the network based on the Mototrbo system is dedicated for crisis management system. There are almost 50 repeaters installed that provide communication services for:

- crisis management system,
- NMES

that are arranged as two sub-networks.

The Mototrbo system is also used for the crisis management in kujawsko-pomorskie voivodeship.

Isolated Mototrbo networks work also in 179 units of the Prison Service. Each radio installation in prison facilities has a single repeater and provides services for ca. 9 terminals. Moreover this system is used by:

- the Border Guard,
- the Municipal Guard in many cities (e.g. Bielsko-Biała),
- Police as isolated networks in many districts (e.g. in lubuskie voivodeship),
- utilities (e.g. heating company in Gliwice),
- medical emergency services within NMES (in Szczecin and Mielec),
- hospitals (e.g. in Toruń),
- enterprises (like Grupa Azoty chemical company, Gas Storage Polska, LOTOS Petrobaltic oil company, PCC Chemicals – Energy – Logistics company in Rokita).

It has been proven that the Mototrbo system is flexible, scalable and reliable. It can be used by many PPDR entities to protect officers' life, ensure resilient communications and provide secure services continuously.

VI. Conclusion

A mass event like "Lednica 2000" Youth Meeting requires efforts to ensure safety and public protection. It is not provided by only PPDR agencies, organizers and supporting organizations but it has to be maintained by technical solutions. In order to coordinate all these entities an efficient wireless communications has to be established. Only PMR networks can ensure reliability and continuity of communication services needed by different task services even in case of a mass incident when mobile networks may suffer the congestion. Experiences collected for recently years allowed creating a good infrastructure for communications and evaluating efficiency of different radio technologies including analog as well as digital radio systems. Even one radio channel in a DMR repeater was sufficient to provide the voice service efficiently. One repeater installed on the roof of Center of John Paul II is capable for a good coverage. To ensure such a communications during the meetings the acquisition of terminals remains a main barrier to handle all task services. Using channels of 12.5 kHz bandwidth, fees for usage of frequency channels are low (especially in this area - rural type of municipality) even if several radio channels are needed. For well and swimmingly organization of the meeting the coordination among groups is needed because they can use different radio communication means. In order to provide such an interoperability the communication center should be established. It is equipped with at least three fixed terminals that are operated by two persons. The communication service starts working very early in the morning on the day of the meeting and finishes its duties next day before the dawn. That is why a few volunteers are involved because it allows organizing shifts.

Acknowledgements

We express acknowledgment to Mirosław Derengowski, Maciej Skoraszewski, and Henryk Paluszkiewicz from Polish Power Transmission and Distribution Association (PTPiREE) for never-ending discussions related to radio dispatching networks. We would like also to thank Stanisław Słowik from AKSEL for his valuable remarks to this paper. For many years the communication center has been organized by volunteers:

Tomasz Adamczyk, Szymon Czyżak, Adam Golon, Magdalena Fryska, Bartosz Kanik, Marcin Kordasz, Paweł Obliżajek, Artur Schreiber, Ireneusz Żmuda and others.

REFERENCES

[1] GSMA, 2017, "Network 2020: Mission Critical Communications".
[2] Roger Coudé, "Radio Mobile", www.ve2dbe.com (access on 19th March 2019).
[3] AKSEL, ConSEL, www.consel.pl/produkty/2/consel_pro/ (access on 19th March 2019).
[4] User's Guide, DrayTek Vigor2926 Series, Dual-WAN Security Router, v. 1.0, 2018.
[5] Dominik Sobieraj, Sławomir Fryska, "10 lat MOTOTRBO w Wielkopolsce" ("10 Years of MOTOTRBO in the Greater Poland"), Magazyn Radiokomunikacji Profesjonalnej, RadioTech, Nr 6/2017 (in Polish).
[6] Dariusz Dymek, "Łączność cyfrowa w województwie wielkopolskim" ("Digital Communications in Wielkopolskie Voivodeship"), RadioEXPO 2014, Warszawa (in Polish).