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Exclusive Implementation of 2.5G LMRS for the First Time in Iran: A Case Study in Khorasan Razavi Electric Power Distribution Company

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Abstract - Having the longest medium voltage overhead lines in the country and an area of 117000 square kilometers, the electricity distribution company of Khorasan Razavi province is a leading communication category company. Maintenance and repair operations on medium and low power lines are carried out by 31 electricity management offices using their own communication systems between vehicles, groups, and centers. As part of its recent experiences, this company has moved from first-generation (analog) land mobile radio system (LMRS) systems to second-generation (digital) systems and into third-generation (software integration) systems. As a result, radio coverage has improved by 38%, SAIDI has reduced by 48%, maintenance cost has decreased by 20%, and more than 5000 calls that were created in the single month can be made in only one city. There are several other advantages to the second generation network created, including the possibility of the integration of communications with other organizations, the creation of various hierarchical groups such as crisis and managers, as well as instant text messaging. Additionally, a number of additional benefits are provided, including high-quality voice calls, double the amount of bandwidth available, data security via encryption, compatibility with analog networks (1G), roaming capabilities, the ability to make private-public-group calls, and the ability to manage users and equipment via software applications. Also, in this project, speech recognition of calls with artificial intelligence (AI) and therefore automatic 121 work order insertion are some of the advantages.

Keywords—DMR, LMRS, Integrated System, Radio, XNMS, Dispatcher

I. Introduction

Various studies have been conducted in the field of LMRS networks, but they have focused mostly on their infrastructure, with very few cases involving the vision and definition of third generation [1]. In [2], [3], authors have evaluated the performance of both DMR (TDMA) and P-25 (FDMA) (Phase-1) systems with respect to the network coverage area and support for voice and data applications. Also, authors have proposed a solution to eliminate the drawbacks of DMR and P-25 (Phase-1) systems by using Long Term Evolution (LTE) smart network which offer eNodeB Radio Access Network (RAN) which can provide a dual platform for the convergence of both TDMA and FDMA transmission schemes.

This paper describes a successful implementation of the third generation of DMR as a subclass of LMRS, which has not yet been implemented in Iran. So the architecture described in this paper can serve as a reference for other organizations. We will discuss in detail the achievements of implementing a new generation communication network at this wide scale within Khorasan Razavi Electricity Distribution Company in the following sections. A crucial component of the third generation of communications is the integration of infrastructure and the centralization and hierarchy of management based on IEC61968 standards, and this paper describes the steps we took from generation 1 (Analog) to reach our present position [4], [5]

- Calculation of the number of channels (Trunks) required for obtaining a license from Regulatory (9 frequency) based on the following parameters from 22 May to 6 September 2021:
    1) *Erlang B*
    2) *Grade of Service = 5%*
- Developing a comprehensive frequency plan based on standard color coding, creating different groups such as crisis, managers, security, local, provincial, HV posts, east and west groups based on organizational chart of this company, super distribution post group from 23 July to 22 October 2021.

- Establishing an ISM radio infrastructure for connecting 12 repeater sites to the IP network [1] from 23 September to 30 December 2021.
- Collect network information, install and configure about 500 wireless digital repeaters, automotive, station, and handheld radios from 22 December 2021 to 22 August 2022.
- Setting up three servers including XNMS, dispatcher, and voice recorder from 23 August to 22 September 2022.
- Establishment of a secure and point-to-point connection with a cellular network from 23 September to 24 October 2022.
- Implementing automatic recognition of recorded speeches and connecting to the 121 system from 30 October 2022 to 3 January 2023.
- Implementing a text messaging and GPS system for cars and monitoring them in the dispatching center from 5 January to 20 April 2023.

II. The Proposed Integrated System

An illustration diagram of the LMRS interconnections between the various components is provided in fig. 1. The implemented LMRS system can be divided into three zones: field, communication infrastructure, and application & server zone. In LMRS, base station should be connected to each other through core IP network [1]. All the base station sites in a LMRS are connected to each other via fiber optics or Microwave back haul networks. This IP connectivity in a LMRS is the backbone of trunking through which wireless handheld or vehicular radio user can easily handoff from the coverage area of one base station to another without call drop or disconnectivity from the home network. The handoff principle from one base station to another base station in a LMRS mainly depends upon the Receive Signal Strength Indications (RSSI) levels. Higher the Receive Signal Strength Indications (RSSI) levels larger will be the Signal to Noise Ratio (SNR), which will result in less delay and jitter which will cause low packet drops. Ideal delay in the IP network should be less than 1 msec [6].

According to the proposed structure, the base station (master) will be responsible for routing tasks, while other repeaters (slaves) will operate under its supervision. To reduce traffic load, our company, KEDC, has designated two repeaters for the coverage of the eastern and western parts of the provinces. For monitoring communications and the status of the repeaters, a XNMS server is embedded, and also a Dispatcher server is included for remotely managing all the configurations and radiation power settings of the base stations from the center office. Upon receiving voice commands from each one of the handheld devices, they are automatically stored and converted to text and then some operations using the voice recognition application which is then sent to the “121-notification-software” for power outage procedures. With the use of dialect databases in the Khorasan Razavi province, the accuracy of speech-to-text conversion is achieved approximately 85%. By doing this, subscribers can be automatically notified in the event of a power outage, which is led to the increasing their satisfaction.

Detailed information regarding the implementation of the field zone is provided in the following. The fitness function mentioned in Equation (1) was used to determine the geographical location of 12 repeaters that would provide maximum coverage for the province. A total of 30 sites at an elevation of more than 500 meters above sea level with an infrastructure facilities were selected for this project. Attempts have been made to utilize the company's distribution infrastructure in this regard. Figure 2 illustrates the presented integrated conceptual architecture for better understanding.

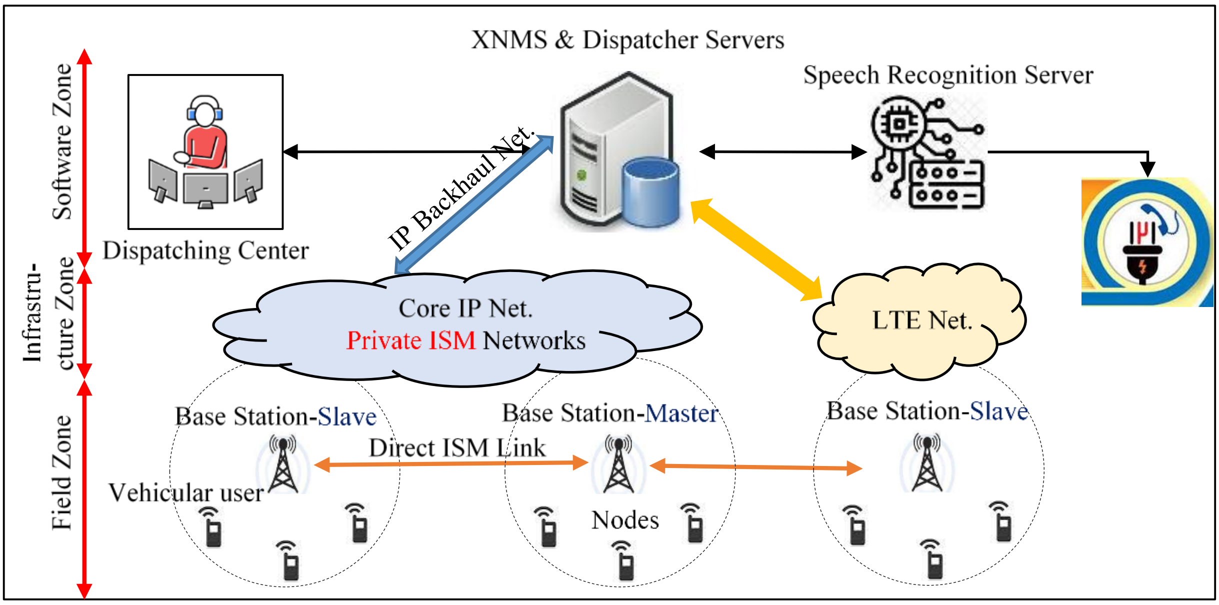

Fig. 1. Block Diagram and Architecture of the Implemented and Proposed 2.5G LMRS system

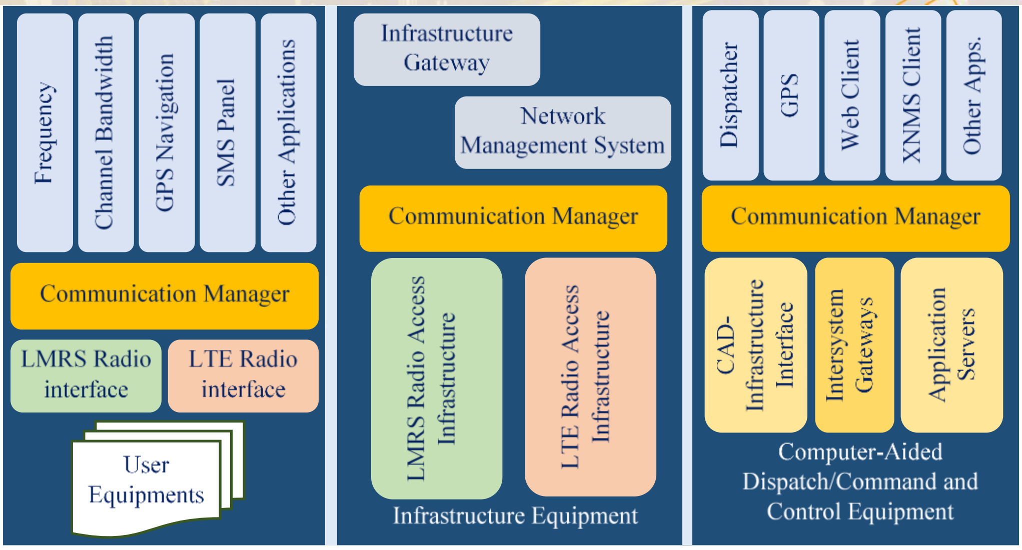

Fig. 2. – Integrated Architecture of the Proposed System with three different Zones

$$Fitness\ Function_i = \sum_{Site=1-30}\sum_{i=1}^{12}\iint_{x,y} K.\frac{P_t.g_t.g_i}{4.\pi.R^2.A_t.A_R}dy.dx \quad (1)$$

The LAT and LON coordinates of each available site are indicated by **Site** in Equation (1). Also, i represents the counter for the 12 selected target sites, K is the attenuation coefficient due to the geographical clutter and dispersion, P_t is the equivalent transmitted power of 25 watts, g_t and g_r are the antenna gains equal to 6 dBi, R is the distance from the antenna in Kilometers, and A_t and A_r are respectively the transmitter and receiver attenuation coefficients. It should be mentioned that coverage calculations were performed using Link Planner 5.6.4 and Forsk Atoll 3.3.2 softwares.

III. Results

As a result of the implementation of the proposed scheme, there has been a significant improvement in the quality of audio within the coverage area. Here is an example of recorded analog and digital audio, along with its Fourier transform, shown in Fig. 3. According to Fig. 3, there is a one-fourth reduction in signal wave energy in the Fourier spectrum in the noise region, supporting the claim made earlier. Further, we have increased coverage from 45% in the old system to 83% in our proposed integrated field zone, which represents excellent coverage for a province with an area of 117000 square kilometers. The achieved coverage level is depicted in Fig. 4. Other technical improvements are summarized in Table 1.

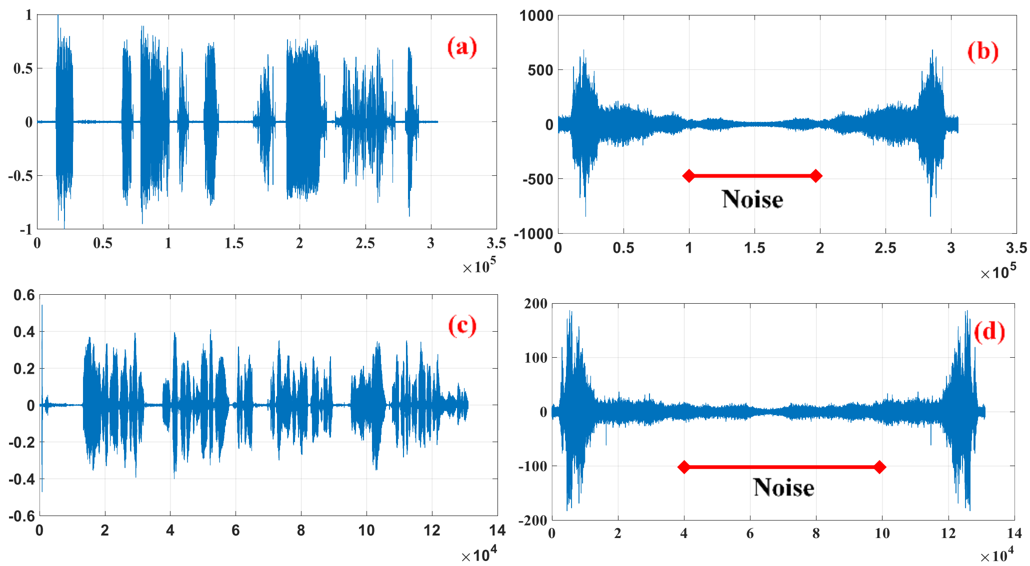

Fig. 3. –Examining the quality of the signal before and after the implementation of the field zone. (a) Analog and (c) Digital Audio Signal, (b) and (d) the relevant Fourier transform.

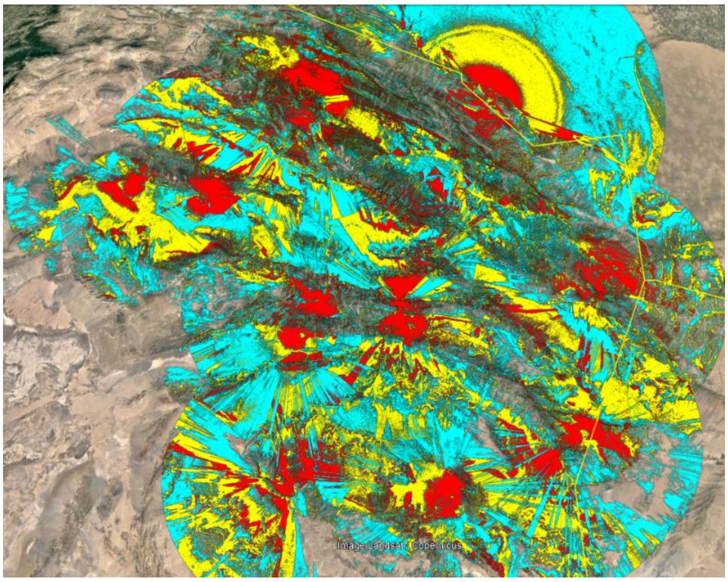

Fig. 4. The coverage level of the proposed system with the mentioned fitness function.

TABLE I. - THE ACHIEVEMENT OF THE PROPOSED INTEGRATED SYSTEM WITH RESPECT TO THE OLD ANALOG SYSTEM.

Row	System	Coverage Level	End-to-End Call Time	GPS	SMS	Applications	Voice Recorder	Security
1	Old Analog System (1 G)	45 %	5 s	✕	✕	✕	✕	✕
2	Proposed Integrated Proposed System (2.5 G)	83 %	2 s	✔	✔	✔	✔	✔

Fig. 5. - Equipment used at the company's infrastructure sites [1]

IV. DISCUSSIONS AND CONCLUSIONS

With the implementation of the 2.5G LMRS project at Khorasan Razavi Electricity Distribution Company, other distribution era has been given new opportunities. Thus, it is an excellent reference when developing such systems. This article presents the achievements quantitatively and qualitatively, as well as highlighting all the challenges and opportunities. This paper have described the implementation and architecture of 2.5G LMRS networks for the first time. As a result of the 2.5G LMRS project, there were 57% more nodes in the province, and coverage levels increased from 45% to 83% which is great for our wide area province. Digital wireless devices are able to repeat sound by designing two parallel sound propagation slots in order to achieve increased radio coverage, which is one of the primary reasons for the increase in radio coverage. These achievements have reduced the company's overall SAIDI in 2022 from 166 minutes to 86 minutes. As an example, Neishabur city averages 5,560 conversations a month, which equals about 23 hours, with an average of 185 conversations per day and 14.6 seconds per conversation. Fig. 5 and Fig. 6 depict equipment used at the infrastructure sites and server pages for monitoring these sites, respectively.

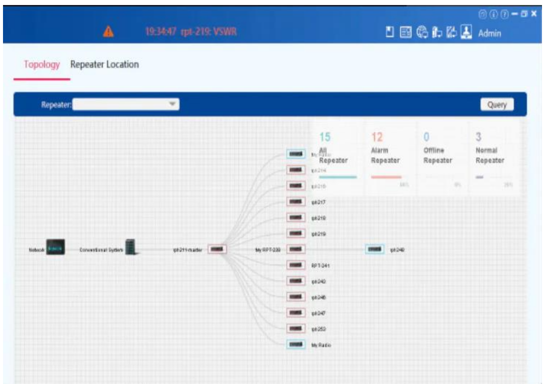

Fig. 6. Server Pages for Managing Repeaters

Based on one-year testing, the implemented system has reached a satisfactory level of stability. In Table 2, which shows the average server log, the accessibility of the system is demonstrated. This table shows that in a period of 36.5 days, the level of accessibility has exceeded 90%, which is suitable for the applications of maintenance groups.

TABLE II. THE NINETH OF AVAILIBILITY

Availability %	Downtime Per Year
90% (one 9)	36.5 days
99% (two 9's)	3.7 days
99.9% (three 9's)	8.8 hours
99.99% (four 9's)	52.6 minutes
99.999% (five 9's)	5.3 minutes

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