

Real Time Performance Analysis of Digital Mobile Radio (DMR) and APCO Project 25 (P-25) Radio Systems in Land Mobile Radio (LMR) Systems

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ABSTRACT

During the occurrence of natural disasters and emergencies uninterruptable voice and data services plays a vital role for the communications of public safety networks. Most reliable form of wireless technology used for the communication between the public safety networks is Land Mobile Radio System (LMRS). Digital Mobile Radio (DMR) and Project 25 (P-25) phase-1 are the part of Land Mobile Radio System (LMRS). Both DMR and P-25 (Phase-1) are designed to operate in the narrowband region of the frequency spectrum for providing uninterrupted voice and data communications to users. DMR use Time Division Multiple Access (TDMA) for voice and data transmission, whereas P-25 (Phase-1) uses Frequency division Multiple Access (FDMA) for voice transmission only. In terms of Spectrum efficiency DMR is more efficient than P-25 (Phase-1) but it cannot accommodate larger network coverage area for Data and Voice transmission. P-25 (Phase-1) repeater can provide a larger network coverage area for voice transmission only. In this paper Authors have evaluate the performance of both DMR and P-25 (Phase-1) systems with respect to the network coverage area and support for voice and data applications. Further Authors have perposed 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.

Keywords: Land Mobile Radio System (LMRS), Digital Mobile Radio (DMR), Time Division Multiple Access (TDMA), Frequency division Multiple Access (FDMA), Long Term Evolution (LTE), LTE eNodeB.

1. INTRODUCTION

The deployment of Land Mobile Radio System (LMRS) can be observed through the world in Military and Civilian sectors. For reliable, efficient and uninterrupted communication between wireless radio users, Land

Mobile Radio System (LMRS) is an ideal technical choice. Land Mobile Radio System (LMRS) are composed of single VHF or UHF bands or dual VHF/UHF bands. For the use of Public Safety communications Land Mobile Radio System (LMRS) is the optimal choice of the wireless communication, as different emergency services like Fire Services, Police Department, Medical Health care can be connected to each other using same frequency channels of VHF/UHF band. Further Land Mobile Radio System (LMRS) allow trunking to wireless users which allow handoff from one Land Mobile Radio System (LMRS) base station to another, without disconnectivity from the home network. Figure 1 depicts the scenario of Trunking and handoff between Land Mobile Radio System (LMRS) base stations deployed in a wide coverage area network [1, 2].

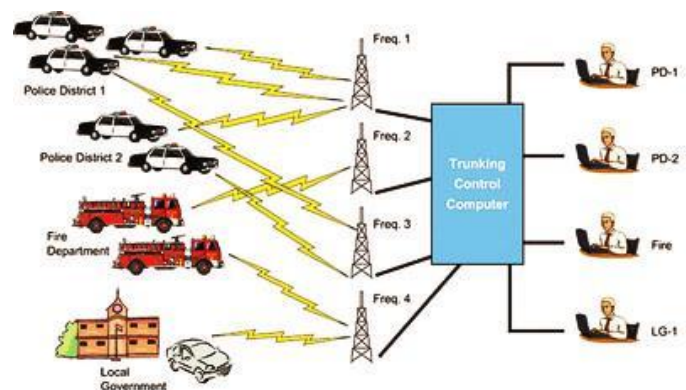


Fig. 1. Trunking in Land Mobile Radio System (LMRS)

In Land Mobile Radio System (LMRS) base station are connected to each other through core IP network. All the base station sites in a Land Mobile Radio System (LMRS) are connected to each other via fiber optics or Microwave

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back haul networks. This IP connectivity in a Land Mobile Radio System (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 Land Mobile Radio System (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 [1, 2].

2. LMR MODES OF OPERATION

A. Simplex or Direct Talk Around Mode of Operation

In Simplex mode of operation hand held, mobile and table top base can communicate with each other without utilizing the Land Mobile Radio System (LMRS) base station unit or network infrastructure. In Direct talk around mode the Land Mobile Radio System (LMRS) users can only communication in the short distance of 1-2Km in ideal scenarios depending upon the topographical conditions of the area. Figure 2 depicts the scenario of Simple point to point communication, where the hand held radios having clear Line of Sight (LOS) have good reception and the radios present in the vegetative areas suffer from poor reception due to foliage. The radios having Non Line of Sight (NLOS) phenomenon due to physical topographical obstruction suffer from no reception and completely disconnectivity from the wireless network [1-3].

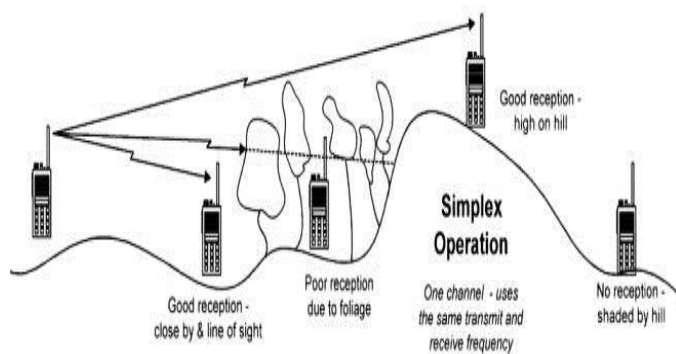


Fig. 2. Simplex Point to Point Communication

B. Duplex or Repeater (Base Station) Mode of Operation

In Duplex mode of operation repeater or base station of the wireless network is involved for communication between the handheld, mobile and table top base. Wireless user first connects to Repeater (base station) of the wireless network for communicating with desired wireless user. Repeater (base station) provides a channel of 12.5 KHz to the wireless user for communicating through the infrastructure network. By using Repeater (base station) the coverage of the Land Mobile Radio System (LMRS) can be increased significantly [1-3].

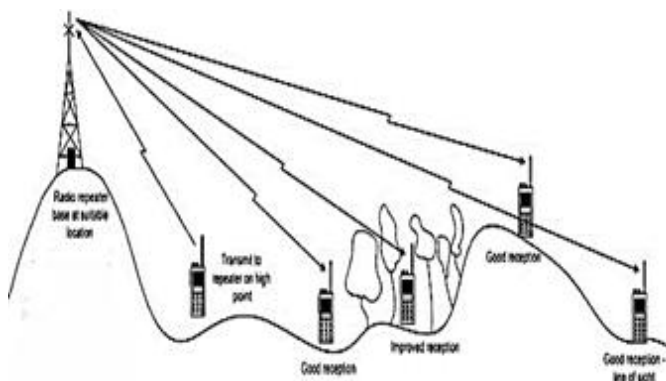


Fig. 3. Communication via Duplex or Repeater (Base station)

Figure 3 depicts the scenario of Simple point to Multi point communication, where a Repeater (base station) of the wireless network is providing access channel of 12.5 KHz to wireless subscriber units. Every wireless subscriber unit has to connect to the Repeater (base station) of the wireless network for communicating to another wireless subscriber unit. In the Land Mobile Radio System (LMRS) Repeater (base station) can only provide access channel of 12.5 KHz to a single wireless subscriber unit, rest of the wireless subscriber units have to wait for their turn. Clear Line of Sight (LOS) between the Repeater (base station) and wireless subscriber units is the major requirement of duplex or Repeater (base station) communication. In a wireless network coverage area due to foliage or physical topographical obstruction will result in a poor or failure of communication from the infrastructure wireless network [1-3].

C. Radio Trunking Mode of Operation

In Trunk mode of operation different Land Mobile Radio System (LMRS) base station sites are connected with each other through a fiber optic system or microwave back haul system, which allow wireless subscriber units to initiate a handoff from the coverage area of one Repeater (base station) to another based on the Receive Signal Strength Indications (RSSI) levels. The wireless subscriber units

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will handoff to the Repeater (base station) which is received with higher Receive Signal Strength Indications (RSSI) levels [2-4].

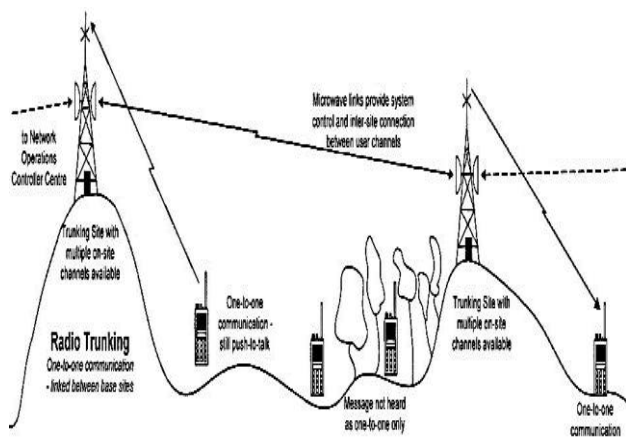


Fig. 4. Radio Repeater (Base Station) Trunking

Figure 4 depicts the scenario of Trunking between the different Repeaters deployed in a wireless network. The wireless subscriber units on the move will initiate handoff from one repeater to another automatically without any hurdles or delays; this will result in a continuous connectivity of the wireless subscriber units with the network infrastructure without any call drop. Land Mobile Radio System (LMRS) can be easily stretched throughout the city in a Wide Area Network (WAN) deployment with the use of trunking. With the help of the trunking phenomenon wireless subscriber units present in the region of foliage or physical topographical obstruction can easily handoff to the nearest repeater (base station) providing Clear Line of Sight (LOS) communication. Trunking uses IP connectivity for connecting the Repeaters (base station) in a Wide Area Network (WAN) deployment. In the absence of the fiber optic network or microwave backhaul network the Repeater (base station) can be connected through the internet cloud. The wireless subscriber units present at two distance places in two different cities can be connected to each other through the internet cloud via dedicated VLANs. Trunking can be used to provide radio network coverage to fire, police, health services and paramilitary forces throughout a city area, countrywide, state/province and particular geographical region. Figure 5 depicts the scenario of Trunking through IP cloud network between the different Repeaters (base station) deployed in a wireless network [2, 3].

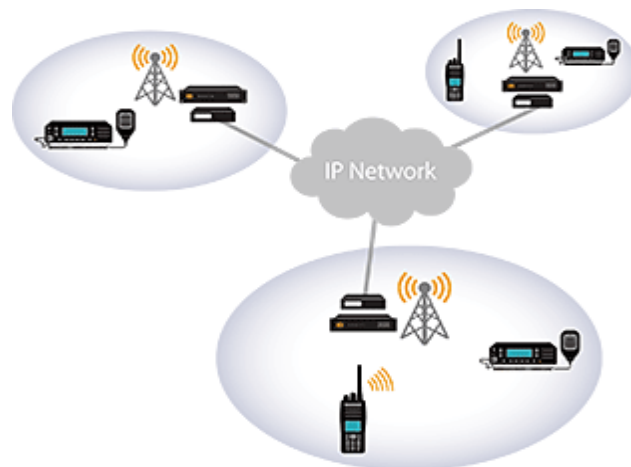


Fig. 5. Repeater (Base Station) Trunking through IP Network

3. DIGITAL MOBILE RADIO (DMR)

ETSI DMR is a digital radio standard specially developed for professional, commercial and private radio users. DMR uses Time Division Multiple Access (TDMA) technique by which it divides a 12.5 KHz channel bandwidth into two 6.25 KHz two logical channels by performing two slot channel mechanism. In DMR each slot can be separately allocated to two different users by the single Repeater (base station) at the same time. This dual slot mechanism allows a single repeater to offer two voice channels to two different users in the network at the same time simultaneously. In DMR first slot can be used for voice and second slot can be used for GPS/Data applications. Figure 6 depicts the dual slot division mechanism [5, 6].

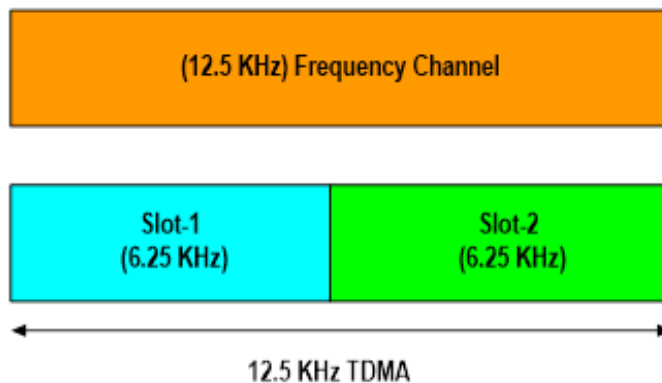


Fig. 6. DMR (TDMA) based Dual Slot Operation Mechanism

In which single 12.5 KHz physical frequency channel is split into two logical 6.25 KHz channels by using TDMA mechanism. Dual slot mechanism of DMR using TDMA mechanism increase the efficiency of the DMR network where two users or two groups can simultaneously access the DMR network without any hurdle or time delays. DMR

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technology is being rapidly adopted by the rescue services where police officer can speak to another officer on first channel (Slot-1) for intra department communications and can switch to second channel (Slot-2) for inter department communications with Fire department officials. DMR also support the Global positioning system (GPS) module which is present in the hand held and vehicular mobile radio sets by which the dispatcher can locate the current position of the user or its vehicle on the digital 3-Dimensional (3-D) MAP using Automatic Vehicle Location (AVL) software. Figure 7 depicts the scenario in which different Repeaters (base station) deployed in a DMR network are connected to the central command and control centre where dispatcher is installed via IP network. Further DMR radios use AES256 and AES128 encryption schemes for safety of radio communications [5, 6].

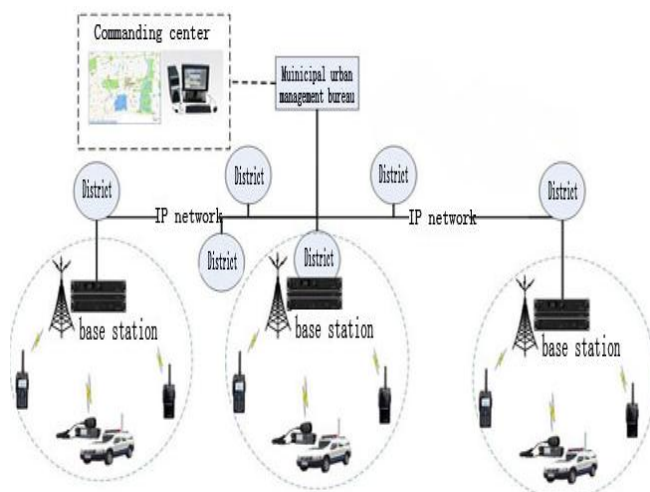


Fig. 7. Dispatcher Operations in a DMR Network

4. STANDARDS OF DMR ASSOCIATION

A. DMR Tier-I

Tier I standard is designed for low power commercial applications like private use and small installations. It operates in license free band of 466MHz. It does not deploy any Repeater (base station) as it is not designed to fulfill the needs of providing communications in a wide area network [6, 7].

B. DMR Tier-II

Tier II standard is designed for conventional radio systems which operate in the band of 66-960MHz. Repeaters (base station) are deployed to fulfill the needs of providing communications in a wide area network. The main objective of Tier-II standard is to provide Integrated IP services and spectral efficiency to hand held, mobile and table top base users by deployment of high power

Repeaters (base station). Tier-II standard is primarily deployed to cover a large installation and city wide area network [6, 7].

C. DMR Tier-III

Tier III standard is designed for trunking radio systems which operate in the band of 66-960MHz. Repeaters (base station) are connected to each other via IP networks through fiber optical system and Microwave backhaul networks. Hand held, mobile and table top base radio users can hand off from one repeater coverage area to another due to IP network trunking. Tier III offer voice, 128 character Short Messaging Service (SMS) and 288 bits of data services in IPv4 and IPv6 packet formats. Tier III standard radios are used for military applications, hence these radios are manufactured according to 810 ruggedized military standards. Figure 8 depicts the scenario of Conventional and Trunked based radio systems. Conventional systems are FDMA based systems where two separate Repeaters (base station) are deployed to provide two separate physical channels to wireless users in the coverage area network. Both Repeaters (base station) are connected to Antenna unit by using combiner equipment. Whereas in Trunked radio systems single Repeater (base station) by using TDMA approach is providing two logical channels to DMR users in the network coverage area. Here the Repeater (base station) is transmitting and receiving via single antenna with the help of duplexer equipment. In DMR Tier III standard a single Repeater (base station) deployed in a wide coverage area network can easily handle two calls simultaneously with the help of TDMA trunking mechanism [6, 7].

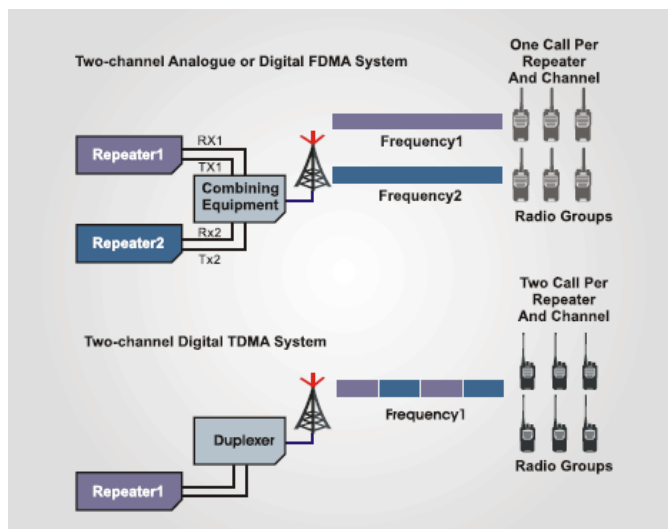


Fig. 8. Conventional and Trunked Radio Systems

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5. Project 25 (P-25)

Association of Public Safety Communications Officials International (APCO) is the founder of the Project 25 (P-25) standard. The Project 25 (P-25) standard was designed to fulfill the needs and requirements of all Public Safety Communications like Fire Services, Police Department, Health care and Para Military forces by using radios systems based on Land Mobile Radio System (LMRS). P-25 radios can operate with legacy radios by using Analog mode and to P-25 radios by using Digital repeater mode. P-25 radios also use AES 256 and DES 56 bit encryption schemes. P-25 radios operates in both Direct Talk around mode (Simplex) and Duplex or Repeater (Base Station) mode of operations [8-10].

P-25 uses low data rate IMBE vocoder of 9600 bps for high quality crystal voice reproduction at the user radio sets. P-25 uses Frequency Division Multiple Access (FDMA) which provide a channel bandwidth of 12.5 KHz. This channel bandwidth of FDMA system is half of the channel bandwidth of Analog 25 KHz FM systems. P-25 by using channel bandwidth of 12.5 KHz allow to accommodate twice as many voice channels within the same allocated spectrum. In P-25 there is no slot operation mechanisms present in the Repeater (base station). Repeater (base station) can only allocate a single channel at one time. Therefore only one P-25 radio user can access the P-25 network Repeater (base station) at a single time [8-10].

6. Phases of Project (P-25)

A. Phase-0

It refers to the legacy and proprietary analog air interface for supporting legacy Analog FM 25 KHz radio systems and infrastructure [8-10].

B. Phase-1

It operates in 12.5 KHz bandwidth and uses Frequency Division Multiple Access (FDMA) scheme. Phase-1 can be used in both conventional and trunking radio systems. In Phase-1 due to the use of FDMA only single individual user is allocated the full channel bandwidth of 12.5 KHz at one time. It cannot support 128 character Short Messaging Service (SMS) and 288 bits of data services in IPv4 and IPv6 packet formats due to the use of (FDMA) scheme. Therefore the use of (FDMA) scheme allows Phase-1 users to have limited capacity and spectrum efficiency. Phase-1 radios due to the use of FDMA scheme utilized more battery power as the handheld radio transmitter has to transmit in the whole channel band of 25 KHz. Therefore the battery of the handheld Phase-1 radio is depleted at the faster rate [8-10].

Phase-1 radios due to the use of (FDMA) scheme can allow large network coverage areas. Therefore the coverage range of Phase-1 Repeaters (base station) is wider as compared to the TDMA scheme based Repeaters (base station). FDMA can easily penetrate throughout the mountainous train and hilly topographical areas. Therefore for fulfilling large area coverage area requirements in Public Safety communications P-25 Phase-1 is the optimum solution for Land Mobile Radio System (LMRS). Due to the provision of trunking systems Phase-1 Repeaters (base station) are interconnected to each other via internet with the help of fiber optics or microwave back haul networks which allow the Phase-1 radio users to initiate handoff from the coverage area of one Repeater (base station) to another based on the Receive Signal Strength Indications (RSSI) levels at the radio [8-10].

C. Phase-2

P-25 Phase-2 is yet to come but it is similar to DMR systems as it uses Time Division Multiple Access (TDMA) technique by which it divides a 12.5 KHz channel bandwidth into two 6.25 KHz two logical channels by performing two slot channel mechanism. In Phase-2 each slot can be separately allocated to two different users by the single Phase-2 Repeater (base station) at the same time. This dual slot mechanism allows a single repeater to offer two voice channels to two different users in the network at the same time simultaneously. In Phase-2 first slot can be used for voice and second slot can be used for GPS/Data applications. Phase-2 by the use two logical channels or two times slots can increase the system capacity as compared to Phase-1 which only have one physical channel of 25 KHz. Phase-2 is more spectral efficient than Phase-1 radios as one Physical channel of 12.5 KHz is divided in two 6.25 KHz logical channels. Figure 9 depicts the use of TDMA in 12.5 KHz physical channel, where two conversations are sharing the same channel simultaneously [5, 8-10].

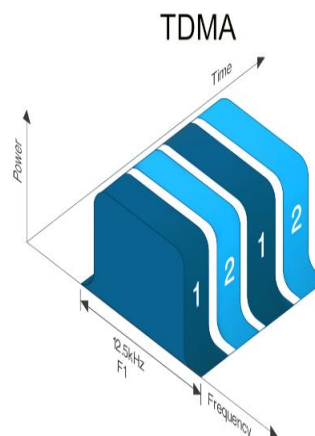


Fig. 9. TDMA Operation in 12.5 KHz Physical Channel

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Phase-2 is backward compatible with the Phase-1 radios and trunking mechanism, present in the Phase-2 radios. The Phase-2 radios due to TDMA scheme utilized less battery power as compared to FDMA Phase-1 radios. In Phase-2 TDMA radios only transmit during the specific time slot time period other than that it remains mute and save handheld battery. Phase-2 is designed to operate in the 700 and 800 MHz band spectrum. Key features of Phase-2 radio systems are the interoperability with old legacy systems, roaming capacity and channel reuse for spectral efficiency [8-10].

7. PROBLEM STATEMENT

In P-25 phase-1 (FDMA) Repeater (base station) can provide a large network coverage area as compared to the DMR network coverage area and cannot support data applications due to lack of spectrum efficiency as only one single physical channel of 25 KHz is utilized only. Whereas DMR (TDMA) Repeater (base station) cannot provide a large network coverage area but it can provide support for voice and data applications due to spectral efficiency as one physical channel of 25 KHz is divided into two logical 6.25 KHz channels or time slots. Hence P-25 (FDMA) and DMR (TDMA) technologies have their own draw backs in terms of battery usage, network coverage and spectral efficiency. The prime objective of this research work is to contribute a solution to allow both P-25 phase-1 (FDMA) radios and DMR (TDMA) radios to operate in a same network domain for avoiding the problem of battery usage, network coverage and spectral efficiency in P-25 (FDMA) and DMR (TDMA) Land Mobile Radio Systems (LMRS) in order to provide uninterrupted wireless communication.

8. PROPOSED SOLUTION

In this research the authors have proposed the use of Long Term Evolution (LTE) networks Repeater (base station) known as LTE eNodeB. LTE eNodeB support the use of both Frequency Division Duplexing (FDD) and Time Division Duplexing (TDD) schemes. LTE eNodeB is a hybrid Repeater (base station) which is composed of both

Frequency Division Duplexing (FDD) and Time Division Duplexing (TDD) schemes. LTE eNodeB can offer high performance Radio Access Networks (RAN) by using VHF and UHF radio bands. DMR and P-25 radios are also based on VHF and UHF radio spectrum; therefore they can be easily integrated with LTE eNodeB technology as it covers the VHF and UHF radio spectrum band.

LTE eNodeB use Time Division Duplexing (TDD) and Frequency Division Duplexing (FDD) schemes which can be easily integrated with DMR Time Division Multiple Access (TDMA) technique and P-25 Frequency Division Multiple Access (FDMA) technique. LTE eNodeB can provide larger network coverage area to p-25 network users and high capacity voice and data traffic to DMR network users. By deploying LTE eNodeB in DMR and P-25 networks we can reduce the cost of deploying separate DMR and P-25 Repeaters (base station). This solution for deploying a single LTE eNodeB Repeater (base station) can dramatically reduce the infrastructure deployment cost of DMR and P-25 Land Mobile Radio System (LMRS) [11, 12].

LTE eNodeB Repeaters (base station) are deployed in the small Pico cells. The use of small Pico cells provides high capacity and increase in network coverage area. LTE eNodeB present in the small Pico cells are self-automated as they can adjust their transmission and reception power according to the current location of the user from the serving LTE eNodeB Repeater (base station). Multiple Input Multiple Output (MIMO) antennas with beamforming can be used to increase the coverage area of the network by increasing or decreasing the transmission and reception powers of the LTE eNodeB Repeater (base station) according to the current location of the user. The use of Pico cells with LTE eNodeB Repeater (base station) allow to support high capacity in terms of flexible user bandwidth for running voice and data applications simultaneously. The use of small Pico cells can reduce the interference at the cell edges by avoiding bleed over of one Pico cell into another, which results in high bandwidth capacity and greater network coverage area. Figure 10 depicts a Long Term Evolution (LTE) network where LTE eNodeB Repeater (base station) is connected to both DMR (TDMA) and P-25 (FDMA) radios. Here LTE eNodeB can provide larger network coverage area to P-25 radios and high bandwidth spectrum efficiency to DMR radios [11, 12].

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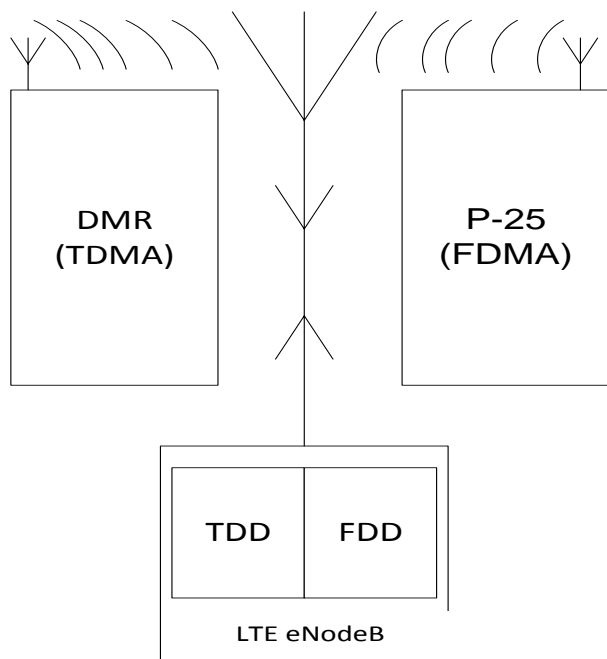


Fig. 10. (TDD & FDD) LTE eNodeB

9. CONCLUSION

Author in this analysis have recommended Land Mobile Radio System (LMRS), DMR and P-25 radio network basic terminologies, architecture and modes of operation. LTE eNodeB use Time Division Duplexing (TDD) and Frequency Division Duplexing (FDD) schemes which can be easily integrated with DMR Time Division Multiple Access (TDMA) technique and P-25 Frequency Division Multiple Access (FDMA) technique. Further by integrating DMR and P-25 radios with LTE eNodeB can reduce the cost of deploying separate DMR and P-25 Repeaters (base station). This solution for deploying a single LTE eNodeB Repeater (base station) can dramatically reduce the infrastructure deployment cost of DMR and P-25 Land Mobile Radio System (LMRS). LTE eNodeB Repeaters (base station) are deployed in the small Pico cells. The use of small Pico cells provides high capacity and increase in network coverage area. The proposed solution for integration of DMR and P-25 radio with LTE networks is a cheap and cost effective solution for infrastructure deployment of future Land Mobile Radio System (LMRS).

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