International Journal on Recent and Innovation Trends in Computing and Communication ISSN: 2321-8169
Volume: 5 Issue: 8 41 – 44

Implementation of High Speed Railway Mobile Communication System

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Abstract**—**High speed railways (HSR) provide highly efficient transport mode which improves the quality of railway services, saves time of the passengers which leads to greater customer satisfaction as well as improves the economics of the society. This has introduced significant challenges like developing new technologies, improving the existing architecture and controlling costs etc. Due to the improvements in the speed, ability to access internet and stream live media there is a requirement of an advanced high speed communication and signaling system. This system demands higher bandwidth, higher reliability and shorter response time for efficient operation and safety. This paper introduces the existing system deployed by the railway based on Global System for Mobile communication (GSM) , analyzes it and presents a much more advanced communication and signaling system based on 4G Long Term Evolution (LTE) technology.

Index Terms**—***High speed railway, LTE, GSM, communication and signaling system,System Architecture Evolution (SAE). (key words)*

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I. INTRODUCTION

With the ever increasing need of high speed transport system,the railways has been developing new ways to increase speed ,reliability,safety and security. Along with these demands there is an immediate requirement to improve the railway communication and signaling system as well as passenger communication for providing high speed internet,high call quality and streaming of live media. One of the widely used train communication system is communication based train control system (CBTC) which provides two way continuous communication,safety control,speed control etc[3].

This control and communication method is old fashioned and requires large number of human operators. Europe introduced European train control system (ECTS) which involves the usage of GSM for internal voice and data communication and CBTC for control command system. Then a railway communication system based on GSM known as GSM-R was introduced which had the same basic network architecture of GSM. However,when traveling speed increases beyond 500 km per hour this system became incompetent to cope up with information loss, handover and shift in Doppler frequency and became unreliable to continue operations[3]. This GSM-R technology has been used for decades since it proved efficient for speed in the range of 200 to 300 km/h.

Due to the introduction of high speed data networks and high travel speed there is a need of a robust high speed system that can maintain operations in high travel speed as well as high speed data network. Thanks to the development of high speed wireless communication techniques,3GPP long term evolution (LTE) is a good option to deal with the discrepancies of the age old GSM-R system[3]. With the rapid development of HSRs LTE-R proves to be a reliable broadband communication system for different HSR components.

International union of railways has been researching on the future of HSR communication system to identify a suitable replacement once the GSM-R becomes obsolete. HSR applications have quality of service (QOS) measures such as data rate ,delay in transmission and bit error rate (BER)[2]. Due to this measures HSR communications generally use low cost and off-the-shelf technologies and add applications over them to fulfill specific demands and operations. GSM-R is a successful example, based on the GSM standard which has been used over 70000 km of railway lines[2]. The GSM-R systems are being replaced as the public communication market is evolving towards the third generation partnership project (3GPP) also known as LTE. So a new system based on LTE has to coexist with GSM-R for a long period of time. The selection of a suitable wireless communication system for HSRs needs to consider such issues as performance, service attributes, frequency band, and industrial support. Compared with third-generation (3G) systems, 4G LTE has a simple flat architecture, high data rate, and low latency, making it an acknowledged acceptable bearer for real-time HSR applications. Fifth-generation (5G) systems, although currently discussed in 3GPP, will be available only after 2020 and, therefore, are not suitable for the HSR time frame. In view of the performance and level of maturity of LTE, LET-railway (LTE-R) will likely be the next generation of HSR communication systems and the future vision for HSR wireless technologies will thus rely on it[2].

LTE-R architecture is based on LTE wireless communication standard and developed from existing GSM/WCDMA core network so, it is backward compatible to older GSM-R based technology. LTE-R architecture reduces operation expenses as well as capital expenditure and features on smooth and simple operation with cost effectiveness deployment therefore LTE technology can be used in a high speed railway communication system as per our demand.

II. GSM-R

GSM-R is similar to the basic network architecture of GSM. MS (mobile station) indicates moving vehicle and radio terminals loaded on the vehicle. Several BTSs (base transceiver stations) deploy along the railway tracks, a SSC (base station controller) controls STSs. The core component of GSM-R system is the network switch subsystem[3]. It includes data gateways, SGSN (service GPRS supporting node) and GGSN (gateway GPRS supporting node), and MSCs (mobile switch centers). Information of users is stored in HLRs (home location registers) and VLRs (visitor locatin registers) assosiated with each MSC in the network. GCR (group call register) stores information about group calls, their configurations and users involved. OMC (operational and maintenance center) manages the entire GSM-R network and billing center collects and records information about GSM-R network used for business and operational purpose[3].

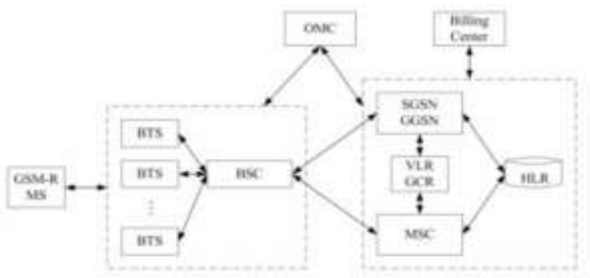

Figure 1. network architecture of GSM-R

The various services offered by GSM-R are voice group call service (VGCS), voice broadcast service (VBS), enhanced multilevel precedence and preemption (EMLPP), functional addressing and location dependent addressing. Although GSM-R is immensely popular and still growing the increase in interference from other networks limits the use of GSM-R while due to the nonavailability of high bandwidth limits its capacity[2]. Some more limitations of GSM-R are as follows:

1. Interference: interference between GSM-R and other public network causes hindrance in voice and data communication and also loss of network coverage between several meters of railway tracks. Interference may increase in future due to the growth of GSM-R network as well as other public networks.
2. Capacity: GSM-R supports 19 channels in its 4MHz bandwidth with each channel of 200KHz. width this bandwidth is sufficient for voice calls however it may be insufficient for advanced railway systems where each coach needs to established a continuous data connection with the base station known as radio block center (RBC) and each connection needs to occupy one time slot.
3. Capability: GSM-R is in capable to adapt to new requirements. the maximum transmission rate of GSM-R is 9.6 kbps which is very low by standard and also it has a message delay of 400 ms which is very high and can cause discrepancies in real time applications and emergency systems. In future there will be a requirement of a system that supports large data bandwidth and shorter message delay[2].

These above limitations are covered by LTE-R which can replace GSM for the following reasons:

1. LTE has far greater capacity,bandwidth and speed.
2. Since LTE is fully packet -switched based network, it is better for data communication.
3. LTE offers reduced packet delay and a more efficient network architecture.
4. LTE has advanced multiplexing and modulation which helps to improve the spectral efficiency which results in high throughput radio access.
5. LTE provides well established and standardized inter working mechanism[2].

III. LTE-R

LTE acts as a unified architecture which provides real time and non real time services with high speed data rate, optimized packet and low latency wireless access technology. Here we will combine the advantages of LTE as a wireless communication system and LTE-R as a new railway mobile communication system based on LTE/System Architecture Evolution (SAE) and analyze it to determine why it is better then existing GSM-R system.

A. ARCHITECTURE

The network architecture of LTE-R is basically similar to LTE/SAE. The existing network architecture of LTE-R is as follows:

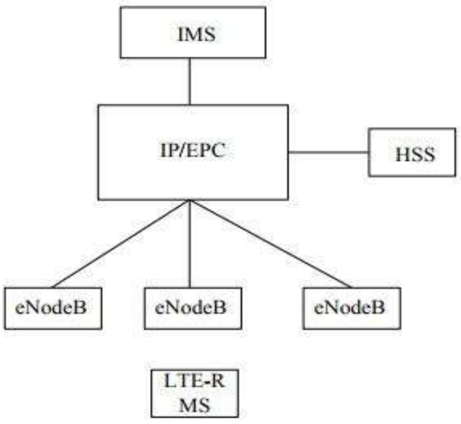

Figure 2. network architecture of LTE-R

The network access structure in LTE-R is called E-UTRAN which replaces Base Station Controller (BSC) in GSM-R. It consist of evolved-NodeB (eNodeB) which is the only network equipment in it as compared to Base Transceiver Station (BTS) and BSE. This network node transmits signal to terminals and receive signals from terminals in one or more cells. It performs functions at physical layer of the architecture related to transmission and reception of radio interface, modulation,demodulation,channel encoding and decoding[1]. It also provides wireless mobility management and can be connected to network router directly without any intermediate nodes as in GSM-R. This results in better compatibility with the follow up networks.

The core network of LTE-R is called Evolved Packet Core (EPC). The difference between the core network of LTE-R and GSM-R is that all the services are built on PS Domain which indicates that EPC is an all IP mobile core network. User registration information is managed by Home Subscriber System (HSS). Mobile Switch Centers (MSC) in GSM-R core network are replaced by IP Multimedia Sub System (IMS) which provides IP Multimedia Services. IMS supports generation of standard IP services by applying Session Initiation Protocol (SIP) as well as effective packet transmission. As a result, LTE-R architecture is relatively flat so the maintenance of the number of devices and network nodes is decreased which makes the network deployment significantly easier with reduced cost[1].

B. TECHNOLOGY

QPSK, 16 QAM and 64 QAM are used in downlink modulation which consist of physical downlink shared channel (PDSCH) and Physical Multi broadcast Channel (PMCH). In Physical Broadcast Channel (PBCH) QPSK is used. For Physical Hybrid ARQ Indicator Channel (PHICH) BPSK (Binary phase shift keying) technology is used. In uplink modulation, QPSK,16QAM and 64QAM technologies are used. For physical uplink shared channel (PUSCH), QPSK,16QAM and 64QAM also can be used. BPSK,QPSK is used for physical uplink control channel(PUCCH)[1]. To reduce the peak to average ratio BPSK, Spectrum Shaping, Selected Mapping and partial transmit sequence technology is used.

In GSM-R system parity code, fire code and block convolution code were used for channel coding. For LTE-R system Turbo code is used. Turbo coding utilizes parallel concatenation to combine convolution code and random inter leaver together which is also known as random coding. Soft input and soft output (SISO) decoding algorithm is used to decode random coding where each decoder has three different type of inputs which are parity,priori and information bits.

LTE-R system uses frequency division multiplexing and multiple input multiple output (MIMO) schemes for modulation. OFDM splits a high-rate data stream into lower-rate data stream by assigning it to mutually orthogonal sub-carriers with low transmission rate. Since the lower rate parallel sub-carriers have longer symbol duration, the dispersion in time caused by wireless channel delayed spread which is also known as multi path delay is decreased. Also guard intervals can be introduced in every OFDM symbol to eliminate inter symbol interference (ISI). While in the guard time, the OFDM symbol can be extended to avoid inter carrier interference (ICI). In LTE-R system OFDMA which is the multi user version of OFDM also can be used to make the scheduling more flexible in the time frequency domain. Users are assigned to different sub carriers to avoid frequency selective fading, based on frequency channel response. QPSK,16 QAM and 64 QAM are used on different sub carriers to transmit downlink data which is time frequency scheduled for different service requirements and channel conditions[3].

Because of higher peak to average power ratio (PAPR) OFDM is not applicable for uplink in LTE-R system. Also it is difficult to use a power amplifier to solve this problem. Data which is sent to eNodeB simultaneously can cause frequency offset problem in uplink transmission due to multiple users so single carrier FDMA (SC-FDMA) is used for uplink transmission. SC-FDMA transmits information symbols in a sequential manner by using different orthogonal frequencies which reduces the envelope fluctuations in the transmitted signal. As a result SC-FDMA signal has a lower peak to average power ratio a compared to FDMA signal. This helps in reducing the physical size, high power consumption of the power amplifier and makes it cost effective.

LTE-R system also supports multiple input multiple output(MIMO) technology,spatial multiplexing, beam forming and transmit density for meeting high needs of data rate and high system capacity. A basic dpwnlink antenna in a LTE-R system consist of 4 antennas: 2 transmit antennas and 2 receiving antennas. Whereas a basic uplink antenna consist of 1 transmit antenna and 2 receiving antennas. The channels are divided into a number of mutually orthogonal sub channels and

ISSN: 2321-8169
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MIMO signal processing is applied in each sub channel which can simplify the equalization and detection of frequency selective MIMO channel. With the help of MIMO multiple data streams can be transmitted and parallel independent channels can be created at the same time. Since in each sub channel MIMO is applied this improves channel transmission rate,spectrum efficiency without increasing the channel bandwidth.

IV. ADVANTAGES OF LTE-R OVER GSM-R

1. Information loss due to high speed train can be overcome by installing roof top antenna which also supports the increasing demand of large data transmission. Roof top antennas are a part of integrated train access unit which collects and distributes information from devices used by the travelers[3].
2. LTE-R systems deal with the doppler frequency problem that hinders frequency handover by allowing the devices accessing network to integrated train access unit. This avoids the devices to get handover without frequently requesting its home network for handover due to frequent changing of cells. This also ensures avoiding group handover problem caused by a number of devices requesting for handover in groups.
3. Because of LTE's flat network architecture it is easily deploy able as compared to GSM-R system and also its lean signaling process makes it to complete the handover in few miliseconds.
4. In a LTE system the minimum sub carrier channel spacing of 15KHz which is tolerant to doppler frequency shift without degrading the orthogonality of the channel. In order to reduce doppler frequency shift we can apply some other techniques like hybrid automatic repeat request (HARQ) and frequency offset correction algorithm (FOCA)[3].

V. CONCLUSION

In this paper we have described the older GSM-R system and the new LTE-R system, its implementation,the technology used and how it fares better than the GSM-R system. LTE-R can solve the current problems with GSM-R and is more effective in providing support for safety and security as well as offering the passengers multiple high end services while high speed traveling. Time has arrived to replace the older GSM-R technology and move towards much more efficient LTE-R technology to meet the ever increasing demand of the railway system. However there are many challenges left for LTE-R to further prove that it will be able to fulfill the requirements of a high speed railway system.

REFERENCES

[1] Gao Tingting and Sun Bin “A High-speed Railway Mobile Communication System Based on LTE,” Beijing, CHINA, pp. 414-417, *ICEIE* 2010.

[2] Ruisi He,Bo Ai,Gongpu Wang,Ke Guan,Zhangdui Zhong,Andreas F. Molisc, Cesar Briso-Rodriguez, and Claude Oestges “High-Speed Railway Communications,” pp. 49-58, September 2016.

[3] Yan Sun, Chang-Young Lee,Jeong-min Jo,Young-Jae Han “Study on the Effectiveness of High-Speed Railway Communication and Signaling System Based on 4G LTE Technology,” pp. 20-23, 2013.

[4] Marina Aguado and Eduardo Jacob, "Railway signalling systems and new trends in wireless data communication," VTC, 2005, Fall

[5] LTE/SAE -The Future Railway Mobile Radio System? Long-Term Visions on Railway Mobile Radio Technologies, UIC, 14.09.2009, V 0.4 Draft.

[6] Xiaohui Ma. The research on the key technology for LTE downlink, Master Thesis of Xi'an University of Electronic Science and Technology, 2009

[7] A. Sniady and J. Soler, “Capacity gain with an alternative LTE railway communication network,” in Proc. 7th Int. Workshop on Communication Technologies for Vehicles, St. Petersburg, Russia, 2014, pp. 1–5.

[8] Richard Van Nee and Ranjee Prasad, "OFDM for wireless Multimedia communications," Artech House, P33

[9] Harri Holma and Antti Toskala, "LTE for UMTS: OFDMA and SC-FDMA based radio access," Wiley, P76

[10] Ralf Zartenar and Ralf Klber "LTE/SAE, Drivers, Benefits and Challenges,"