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A Study of Key Issues in Voice over Internet Protocol (VoIP) Systems

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Abstract. In order to solve the problem of dual-mode switching in NG eCall system network, the research on key problems of network telephone system was proposed. Based on 5G NR protocol and synaesthesia integrated transmission technology, this paper uses extended Kalman filter algorithm to predict and track vehicles. The beam management overhead is reduced based on the active sensing capability of the base station, and the reduced overhead is analyzed numerically. The test results show that the vehicle VIN, power type, etc. are correct after analyzing the MSD received by the comprehensive tester, and the position deviation is only 7.2m, far less than 150m. The MSD analysis obtained from several tests shows that the position deviation is generally2 ~ 12mbetween. Conclusion: This study can effectively improve the compatibility of LTE/5G NR with the existing on-board eCall system, and effectively reduce the upgrading cost of users.

Keywords. Internet of Vehicles; Synaesthesia integration; 5G NR; Beam tracking

1. Introduction

The eCall (Emergency Call Emergency Call) system is a vehicle accident emergency call system launched by the European Union. It is mainly used to automatically or manually send a call for help to the PSAP (Public Safety Answering Point) when a vehicle accident occurs or the crew encounters an emergency, and provide relevant information such as vehicle location [1]. Since the eCall system was applied to cars, data over the years have shown that the eCall system can improve the rescue speed of the injured in road traffic accidents [2]. According to the statistics of the European Commission, the use of eCall system can significantly shorten the rescue time after road traffic accidents (50% in rural areas and 40% in urban areas), thereby saving passengers' lives or reducing the severity of vehicle accident injuries [3].

Due to its early development, most European and American automobile manufacturers still use the traditional 2G/3G network in their eCall systems; At the same time, although China leads the world in 4G/5G mobile communication deployment, many vehicles are not equipped with eCall system due to the lack of relevant mandatory standards [4].

In 2022, the global overall vehicle shipments have not recovered to the level before COVID-19. At present, the global eCall market is concentrated in the EU, Russia, the United Arab Emirates, South Korea, Israel and other regions with eCall policies [5]. According to statistics, the eCall market will reach US $1.678 billion in 2022 (up 4%

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from 2021). Thanks to the recovery of the new eCall market and auto market in Saudi Arabia and China, it is expected to grow to US $9931 million by 2030. Therefore, it is necessary to promote the 5GeCall system that can adapt to the next generation mobile communication network [6].

2. Literature review

Vehicle accident emergency rescue call based on Telematics is based on automotive sensing, mobile communications, satellite positioning and other technologies, the first time after the accident with the public rescue center to get in touch with the location of the vehicle and vehicle information automatically sent to the rescue center, the rescue center to confirm the accident on the rescue of the accident personnel [7]. Internationally, there are a number of countries and regions are or plan to carry out vehicle networking based on vehicle accident emergency rescue call service, the more leading including Europe, Japan, Russia, etc. [8].

In 2005, the European Commission requested the development of an on-board emergency call (eCall) service. The European Commission assigned the technical standard task to ETSI/3GPP (European Telecommunications Standards Institute, ETSI) to develop and establish an eCall communication technology standard system [9]. In 2008, ETSI/3GPP began to issue a series of technical standards for eCall communication modules. In 2011, nine European countries jointly founded the HeERO (Pan European Vehicle Emergency Call Service) Alliance. The EU issued Regulation 2015/758 in 2015, and the Commission Implementation Regulation (EU) 2017/78 and Commission Delegation Regulation (EU) 2017/79 in 2017 [10]. The European Union's eCall policy stipulates that from March 31, 2018, all new M1 and N1 vehicles will be forced to install on-board eCall systems. Since the launch of UNECE-R144 in 2018, Japan has required mandatory installation of emergency call system (AECS) for M1/N1 vehicles for new models after the 1.5 year transition period; For vehicles in production, Japan requires mandatory installation of AECS on M1/N1 vehicles after a three-year transition period. According to Japanese official statistics, AECS will save an average of 4 minutes of rescue time. At the same time, the D-Cal system of Japan's advanced rescue service is expected to save an average of 17 minutes [11]. India stipulates that from April 1, 2019, all passenger cars, such as taxis and buses, must be equipped with AIS140 tracker equipment. The researchers proposed to use Bayesian filtering method to design the beamforming design algorithm of the Internet of Vehicles based on synaesthesia integration, such as extended Kalman filtering algorithm and message passing algorithm [12]. To track extended vehicle targets.

With the rapid development of the Internet of Vehicles, the on-board eCall system can establish voice connection with the rescue center after a traffic accident by using mobile phones and satellite positioning functions. Focusing on the LTE/5G NR without circuit domain, the project can transmit more multimedia information and accident diagnosis information for NG eCall using IMS with high bandwidth and low delay. The project focuses on solving the key problem of dual-mode switching in NG eCall system network, which can effectively improve the compatibility of LTE/5G NR with the existing on-board eCall system and effectively reduce user upgrade costs.

3. Methodology

3.1. Problems in Existing eCall System Technology

The eCall system has been deployed on a large scale in Europe, and it is mandatory for new cars to be equipped with this function since March 2018 according to the law. At present, a typical eCall system includes at least the following parts: 1. GNSS (Global Navigation Satellite System) receiver; 2. GNSS antenna; 3. NAD (Network Access Device, including SIM card); 4. Mobile network antenna; 5. ECU (Electronic Control Unit); 6. Microphone; 7. Loudspeaker/emergency pager; 8. Manual key; 9. Battery or power supply system; 10. Warning or indicating device; 11. The typical system structure of the collision detection system (sensor) is shown in Figure 1 [13].

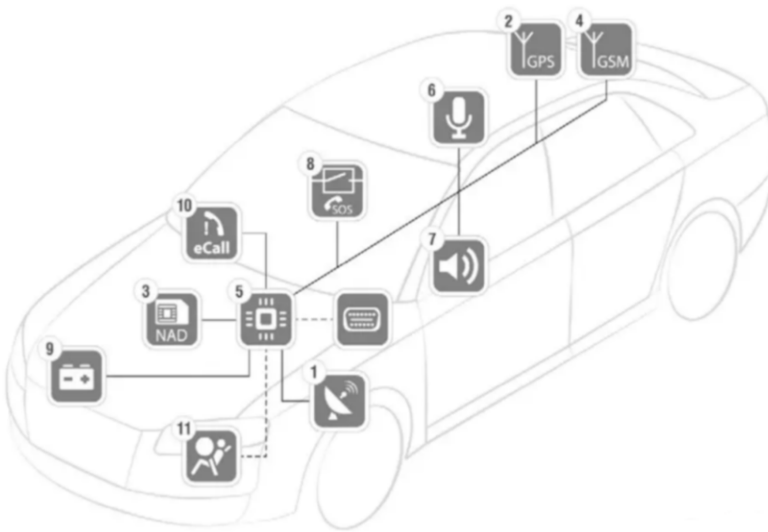

Figure 1. Typical eCall System Structure

The working principle of the existing eCall system is to start the voice call between the vehicle and the PSAP through IVS (In Vehicle System), and send the MSD (Minimum Data Set) [14]. Based on 2G (GSM)/3G (UMTS) C/S (Circuit Switching) standards, eCall services are widely covered in EU countries [15]. At present, the mainstream adopts the In band Modem Call scheme (in band modulation and demodulation eCall), uses the 2G/3G network's ability to support C/S domain emergency calls, uses the in band modulation technology to multiplex the MSD time division and modulate it to the digital voice passband, and then transmits it to the PSAP through the 2G/3G voice channel [16].

However, the traditional In band Modem Call mode based on 2G/3G networks has the following main problems to be solved:

- Due to the rate limitation of the in band voice transmission channel in the C/S domain, only 140 bytes of basic information can be transmitted, and data cannot be flexibly added and adjusted.

- The concurrency of voice and packet data between the IVS and the same PSAP cannot be effectively supported. Therefore, in band Modem Call cannot transmit more group data information such as live images and videos to the PSAP. If the personnel in the car are seriously injured and cannot speak, it is difficult for the personnel of PSAP to learn more about the on-site situation and provide more targeted remote rescue guidance for the injured [17].
- 2G/3G networks around the world are gradually retiring, and European mobile network operators have begun to retire UMTS. Major European countries will phase out GSM networks in the next 10 years, and plan to transition to eCall systems based on 4G/5G mobile communication networks from 2030 to 2035.

3.2. Technical features of NG eCall system

NG eCall (Next Generation eCall) standard was developed in 2013, initially based on the LTE network. An SIP/IP channel is established through the IMS (IP Multimedia Subsystem IP Multimedia Subsystem) in the LTE network to transmit emergency calls through VoIP. If PSAP uses the C/S domain instead of the P/S domain, MGW (Media Gateway Media Gateway) will convert VoIP back to the C/S domain to transmit voice [18]. The subsequent NG eCall adds support for 5G NR. The transmission diagram of NG eCall system based on 5G NR is shown in Figure 2.

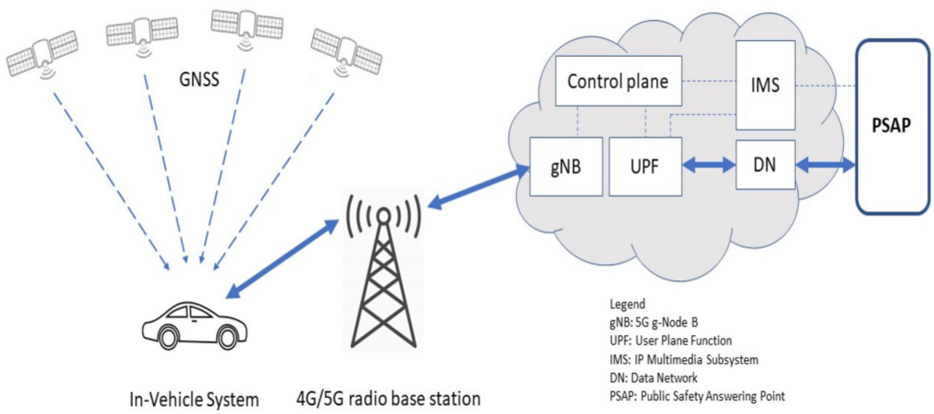

Figure 2. Transmission Diagram of NG e-Call System

In the NG eCall system, LTE/5GNR will also be able to transmit multimedia content, such as information from the instrument panel and video and audio messages in the car [19] due to its significantly improved carrying capacity and faster MSD data transmission. The control channel from PSAP to IVS will allow remote commands to be sent, such as honking the horn, flashing the lights, locking or unlocking the doors, turning off the vehicle ignition switch, etc. These will undoubtedly greatly improve the information transmission capability of the vehicle in emergency and the ability of PSAP to guide on-site rescue, and reduce the casualty rate of traffic accidents [20].

3.3. System and channel modeling

In this paper, we consider a base station equipped with a massive uniform surface array communicating with a vehicle traveling along a straight line in the millimeter-wave band. All parameters are defined in the time period that $t \in [0, T_{\max}]$ Within, among others $T_{\max}$ denotes the longest simulation time, and can be divided into several shorter time periods ΔT. Vehicles in the first n The angles, distances and velocities in a time period can be expressed as, respectively, the $\boldsymbol{\theta}_n$、 $\boldsymbol{d}_n$ and v_n。

3.3.1 Radar signal modeling

In the nth time period, the echo received by the base station from the target and K-1 reflector can be expressed as:

$$\boldsymbol{r}_n(t) = \zeta\sqrt{p}\sum_{k=1}^{K}\beta_{k,n}\mathrm{e}^{\mathrm{j}2\pi\mu_{k,n}t}\boldsymbol{b}(\boldsymbol{\theta}_{k,n})\boldsymbol{a}^H(\boldsymbol{\theta}_{k,n})\boldsymbol{f}_n\sum_{m=0}^{M-1}\sum_{l=0}^{L-1}s_{m,l}\mathrm{e}^{\mathrm{j}2\pi m\Delta f(t-lT_s-\tau_{k,n})} + z_r(t) \tag{1}$$

Among them $\zeta = \sqrt{N_t N_r}$ denotes the array gain, the N_t、 N_r denote the number of transmitting antennas and the number of receiving antennas of the base station, respectively. p indicates the transmit power. $\beta_{k,n}$ and $\mu_{k,n}$ denote, respectively, No k Reflection coefficients and Doppler frequencies of individual reflectors.M、 L and Δf It respectively represents the number of subcarriers, the number of symbols and the subcarrier spacing of OFDM.$s_{m,l}$ Indicates that the first$m$subcarriers and th$l$transmitted data carried on a symbol.T_s Indicates the duration of an OFDM symbol, z_r denotes additional Gaussian white noise.

The emission guidance vector of the uniform face array of the base station can be expressed as follows.

$$\boldsymbol{a}(\boldsymbol{\theta}_{k,n}) = a(\theta,\phi) = v_{az}(\theta,\phi) \otimes v_{el}(\phi) \tag{2}$$

Among themθandϕwhich represent the azimuth and pitch angles, respectively.

$$\boldsymbol{v}_{az}(\theta,\phi) = \sqrt{\frac{1}{N_{t,x}}}\left[1, \mathrm{e}^{\mathrm{j}\pi\sin\theta\cos\phi}, \ldots, \mathrm{e}^{\mathrm{j}z(N_{t,x}-1)\sin\theta\cos\phi}\right]^{\mathrm{T}} \tag{3}$$

$$v_{el}(\phi) = \sqrt{\frac{1}{N_{t,y}}}\left[1, \mathrm{e}^{\mathrm{j}\pi\sin\phi}, \ldots, \mathrm{e}^{\mathrm{j}\pi(N_{t,y}-1)\sin\phi}\right]^{\mathrm{T}} \tag{4}$$

Among them$N_{t,x}$、 $N_{t,y}$denote the number of antennas per row and column of the uniform surface array, respectively.

3.3.2 Radar observation models

After sampling and Fourier transformation of the received continuous signal, the discrete signal received on the m-th subcarrier, the l-th symbol and the i-th antenna can be expressed as:

$$r_{m,l} = \zeta\sqrt{p}\sum_{k=1}^{K}\beta_k\left[\boldsymbol{b}(\boldsymbol{\theta}_{k,n})\right]_i\boldsymbol{a}^{\mathrm{H}}(\boldsymbol{\theta}_{k,n})\boldsymbol{f}_n\mathrm{e}^{\mathrm{j}\pi 2\mu_{k,n}(l-1)\tau_s}\mathrm{e}^{-\mathrm{j}2\pi(m-1)\langle f_{k,n}}S_{m,l} \tag{5}$$

The time delay and Doppler frequency of the target are calculated by dividing the received and transmitted signals by their corresponding elements to obtain its precise position and velocity.

$$r_{m,l} = \frac{r_{m,l}}{s_{m,l}} = \zeta\sqrt{p}\sum_{k=1}^{K}\beta_k\left[\boldsymbol{b}(\boldsymbol{\theta}_{k,n})\right]_i \boldsymbol{a}^H(\boldsymbol{\theta}_{k,n})\boldsymbol{f}_n \mathrm{e}^{\mathrm{j}2\pi\mu_{k,n}(l-1)\tau_r}\mathrm{e}^{-\mathrm{j}2x(m-1)\hat{u}\tau_{k,n}} \quad (6)$$

Through integration$M$Subcarriers, we can find the corresponding peak value in the snapshot and slow snapshot dimensions of the signal data on the antenna, and then obtain the corresponding distance and relative speed of the target and the scatterer. The azimuth and pitch angles are obtained by MUSIC algorithm.

3.3.3 Communication model

The signal received by the vehicle after beam fouling at the receiver can be expressed as follows.

$$c_n(t) = \tilde{\zeta}\sqrt{p}\sum_{k=1}^{\mathcal{K}}\tilde{\alpha}_{k,n}\boldsymbol{v}_n\boldsymbol{u}(\boldsymbol{\theta}_{k,n})\boldsymbol{a}^{\mathrm{H}}(\boldsymbol{\theta}_{k,n})\boldsymbol{f}_n\sum_{m=0}^{M-1}\sum_{l=0}^{L-1}s_{m,l}\mathrm{e}^{\mathrm{j}2\pi m\Delta f(t-IT_s)} + z_c(t) \quad (7)$$

Among them $\tilde{\zeta} = \sqrt{N_t M_r}$ denotes the array gain, the M_r denote the number of receiving antennas of the vehicle face array, respectively. $\tilde{\alpha}_{k,n}$ denote the channel coefficients of different paths.

Here, the SNR (Signal to Noise Ratio) is defined as$SNR_t = p/\sigma_c{}^2$The SNR of the receiver is:

$$SNR_r = \frac{p\left|\tilde{\zeta}\sum_{k=1}^{K}\tilde{\alpha}_{k,n}\boldsymbol{v}_n\boldsymbol{u}(\boldsymbol{\theta}_{k,n})\boldsymbol{a}^{\mathrm{H}}(\boldsymbol{\theta}_{k,n})\boldsymbol{f}_n\right|^2}{\sigma_c^2} \quad (8)$$

Among them $\sigma_c{}^2$ denotes the variance of the white Gaussian noise at the receiver.

*3.4. **5G** NR Sense Auxiliary Communication*

3.4.1 NR frame structure

Similar to LTE, 5GNR still uses OFDM waveform with cyclic prefix. NR supports up to 7 parameter sets, and each parameter set represents the subcarrier spacing and parameter set number μ The relationship between the $\Delta f = 2^{\mu}.15\mathrm{kHz}, 0 \leq \mu \leq 6$。 Although NR supports different parameter sets, the wireless frame length and subframe length of different parameter sets remain unchanged, which are 10ms and 1ms respectively. Each subframe can be further divided into2^{μ}Each time slot consists of 14 symbols with normal cyclic prefixes or 12 symbols with extended cyclic prefixes. Under dynamic time division multiplexing, the symbols in the time slots can be used for downlink, uplink and flexible configurations, providing more possibilities for different transmission situations.

3.4.2 NR beam management

Beam management is an important part of link establishment and maintenance between user equipment and millimeter-wave base stations, and is widely used for initial access of idle users and beam tracking of accessed users to provide optimal beam pairs and to improve beam fouling gain and communication quality.

- Initial access

The initial access consists of three stages. The base station searches for the best downlink beam through the scanning beam shaped synchronization signal block, the channel state information reference signal (CSI-RS) and the feedback provided by the user. The base station sends the best downlink beam repeatedly to scan the beam on the user side, selects the best uplink beam, and then establishes the best beam pair.

- connection mode

After the initial access, the data transmission link between the user and the BTS has been formed, and the user has changed from idle mode to connection mode. In order to facilitate the user to obtain the transmission resource scheduling information, the downlink control channel carrying downlink control information will be transmitted first. The transmission data will be mainly carried by the downlink shared channel, in which a variety of reference signals are embedded, such as demodulation reference signal (DMRS), CSI-RS and phase tracking reference signal (PTRS). DMRS is mainly used for coherent demodulation of data, and NR supports different embedding methods, densities and additional DMRS. CSI-RS is used to obtain downlink channel status information, and its configuration in NR is very flexible. Specifically, the base station can be configured with up to 32 CSI-RS antenna ports, and two codebooks are available based on the number of panels and the number of users in MIMO. CSI-RS feedback reports often include parameters such as RI, Rank Indicator, PMI, Precoding Matrix Indicator, and CQI, Channel Quality Information. PTRS is mainly used to compensate the phase error caused by local oscillator.

- NR based synaesthesia integrated Internet of Vehicles

All the reference signals mentioned above can be regarded as overhead in the communication system, because the time-frequency resources they occupy transmit signals known to both the sender and receiver, rather than user data. Excessive overhead will limit the communication performance, especially in the highly dynamic application scenario of the Internet of Vehicles. The CSI-RS embedded in the downlink shared channel is mainly used for channel detection, and its feedback parameters such as the precoding matrix can be used to design the beam shaping in the next cycle. However, if the synaesthesia integration signal is reasonably used in the Internet of Vehicles, it will effectively reduce the use of reference signals and improve the throughput of the overall system.

Specifically, consider a single user single layer MIMO Internet of Vehicles scenario. The CSI-RS uplink feedback report includes PMI, CQI and other information. However, using the echo of synaesthesia integrated signal, the base station can extract a lot of dynamic information about the vehicle from the echo, and judge the quality of the channel from the feedback echo power. This information can be used to design the beam shaping of the next slot. Therefore, in the synaesthesia integrated car network, the transmission of CSI-RS can be abolished, and the time-frequency resources occupied by CSI-RS can be used to transmit communication data, which will reduce the overhead of the communication system and improve the throughput of data transmission. On this basis, the extended Kalman filter can be used to predict and track the dynamic parameters of vehicles.

3.5. Improved NG eCall system architecture

One of the key issues of this topic is how to ensure the smooth transition from the existing eCall system to the NG eCall system. Considering that LTE/5G NR has no circuit domain, NG eCall requires vehicles to support NG eCall during deployment, and only needs to make appropriate modifications to the PSAP to support IMS calls. But, The deployment of NG eCall mainly depends on the successful implementation and wide coverage of VoLTE and IMS emergency calls in the packet domain. Therefore, the research team expects that in a quite long period of time, the In band Modem eCall mode may still be required, and both eCall and NG eCall modes need to be supported during the transition period, so as to ensure that the vehicles of the previously deployed eCall system can continue to use emergency rescue services. The on-board eCall system needs to support dual mode. When the network does not support NG eCall, it can fall back to In band Modem eCall mode.

The system architecture of the improved NG eCall is shown in Figure 3. The main network elements include the cellular network supporting IMS based emergency calls, IVS (vehicle mounted station) supporting NG eCall functions, and PSAP (public security response point, i.e. rescue platform) supporting NG eCall functions. In order to ensure that the on-board station can send the vehicle emergency alarm even though it is in the 4G/5G network but outside the VoLTE/IMS coverage area under the 2G/3G network.

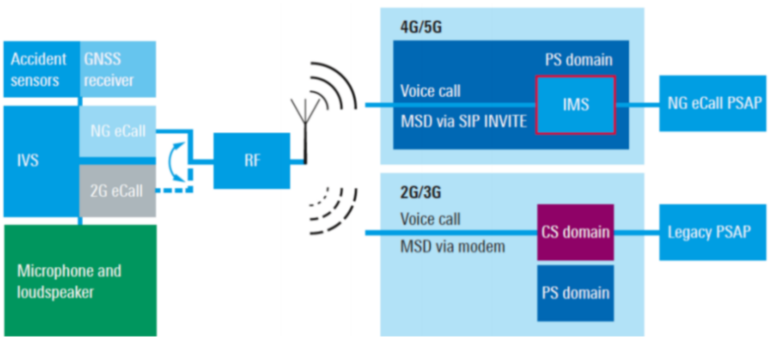

Figure 3. System architecture of improved NG eCall

4. Results and discussion

This paper discusses the whole vehicle level test of NG eCall on-board system to evaluate its automatic triggering characteristics, the correctness and accuracy of MSD and voice communication performance in case of traffic accidents. In order to avoid interference from other communication signals in the test, spectrum investigation and confirmation of signal coverage are required before the test to ensure that the channel used by the base station simulated by the comprehensive tester is not occupied and the signal strength received by the IVS of NG eCall in the entire test area is better than - 60dBm.

The background noise values at the test site were measured prior to the test, and the results were48.9dB(A)。 The minimum signal strength received by IVS in the whole test area is - 56dBm. After the collision in the sample year, the IVS was automatically triggered. After successfully sending the MSD to the comprehensive measuring instrument, it automatically switched to the voice call channel mode, and made a normal voice call with the comprehensive measuring instrument. After analyzing the MSD received by the comprehensive tester, the vehicle VIN, power type, etc. are correct, and the position deviation is only 7.2m, far less than 150m. The MSD analysis obtained from several tests shows that the position deviation is generally $2 \sim 12$m Between.

5. Conclusion

This paper proposes the research on the key problems of the network phone system, and improves the original eCall system, which mainly focuses on voice signals. Aiming at the low delay, high reliability, and large bandwidth provided by the 5GR16 protocol, it provides information such as vehicle condition reports, driving reports, fault alerts, location tracks, and driving behavior monitoring in emergencies, providing richer rescue information in emergencies. In view of the fact that the existing vehicles are still dominated by the eCall system, the transmission algorithm has been improved to determine whether the 5GeCall system that does not support the C/S domain can also be connected with the original eCall system, so as to achieve a smooth transition of the original eCall system.

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