World Journal of Advanced Research and Reviews

eISSN: 2581-9615 CODEN (USA): WJARAI

Cross Ref DOI: 10.30574/wjarr

Journal homepage: https://wjarr.com/

(Review Article)

A review on autonomous electric vehicle communication networks-progress, methods and challenges

Ashwin Kavasseri Venkitaraman [1, *] and Venkata Satya Rahul Kosuru [2]

[1] *Department of Engineering, Electrical Engineering, University of Cincinnati, Ohio, USA.*

[2] *Department of Engineering, Electrical and Computers Engineering, Lawrence Technological University, MI, USA.*

World Journal of Advanced Research and Reviews, 2022, 16(03), 013–024

Publication history: Received on 18 October 2022; revised on 28 November 2022; accepted on 30 November 2022

Article DOI: https://doi.org/10.30574/wjarr.2022.16.3.1309

Abstract

Electric vehicles have gained significance owing to its unavoidable supporting factors including environmental impacts and climate features. It has been noticed over last few decades that the increased number of manufacturers have focused on electric propulsion-based technology either pure electric or hybrid form with the support of electric vehicles in the automotive market. The adoption of these electric vehicle has obviously increased its competitive nature while compared to traditional internal combustion engine system. Moreover, the electric vehicles (EVs) possess substantial potential, not only in minimizing carbon emission but also in assisting required energy storage to contribute to the distributed renewable generation. There exist several increases in electric vehicle usage, but their level of massive adoption and existence by automotive consumers is connected with its delivered performance. One such important feature is the autonomous electric vehicle communication networks. This research provides a comprehensive review on overview of the electric vehicles and will discuss various existing works on autonomous driving vehicles. The paper compares existing communication networks and nuances associated in the context of an autonomous electric vehicle. Also, it critiques the existing technology and provides suggestive future work in the field to make communication networks resilient. An extensive review makes it possible to ascertain future research directions in the EV research field, which would result in massive future and instantaneous EV perception in the automotive market.

Keywords: Network Communication; Wireless Technology; Latency; Resilience; Transmission rate

1. Introduction

The electric vehicle and its popularity have been expected to be the future mobility by the auto industry field and the main original equipment manufacturers in a global level [3] [46]. In upcoming years, the electric vehicle would have an advisable role in smart cities with shared mobility and public transport [1] [49]. Self-driving or autonomous vehicles are upcoming generation vehicles which possess the capability to identify and sense surrounding atmosphere and act according to that [47] [48]. This is self-driving or driver less technology in which the vehicle itself fixes the route for travel, senses road condition whether travel is possible and operates vehicle to reach end destination set by the customer [50]. As per "National Highway Traffic Safety Administration", there are six major phases of autonomous vehicle development framed. They are

- "L0 – no automated driving,
- L1 – driver assisted driving,
- L2 – semi-automated driving,
- L3 – highly automated driving,
- L4 – fully automated driving,

* Corresponding author: Ashwin Kavasseri Venkitaraman

Department of Engineering, Electrical Engineering, University of Cincinnati, Ohio, USA.

- L5 – driverless phase [2]".

Autonomous driving by means of vehicles with the perception ability has been discussed in several contexts and particularly, an automatic means of lane keeping function has been implemented already in some of the cars sold to general public [51]. There are several challenges existing in which one challenge execution of complex form of driving maneuvers in connection with surrounding vehicles. Wireless means of communication among vehicles and infrastructure is one way of evolving autonomous driving a step more [4].

While environment is considered, the social factors get affected and the governance might end up in bribery. Hence, these factors are pulling forces to each other which requires appropriate consideration while introducing mining projects. There are several impacts with respect to mining activity and the world climate change crisis has shown up recently [52] [54]. Moreover, when mining is executed for energy transition metals, social issues occur like land degradation, farming might be affected, water resources might get affected. When mining gets increased, the ESG (environmental, social and governance) concern arises [53].

However, the technological way of development which relates the energy source of electric vehicle propulsion stays far from assisting advanced or energy efficient technical based solutions. Some of the immediate issues required to be solved in this aspect [7] [8].

The electric cars, buses and the neighborhood electric cars could be massively classified as electric vehicles and stays as a principal means of transportation system in future [56]. Major tendency of decreasing the gas emission in city would guide the total electrification of the transport system [28]. However, in a normal city, these transportation systems could not be guaranteed and hence, a smart city could attain this vision [55].

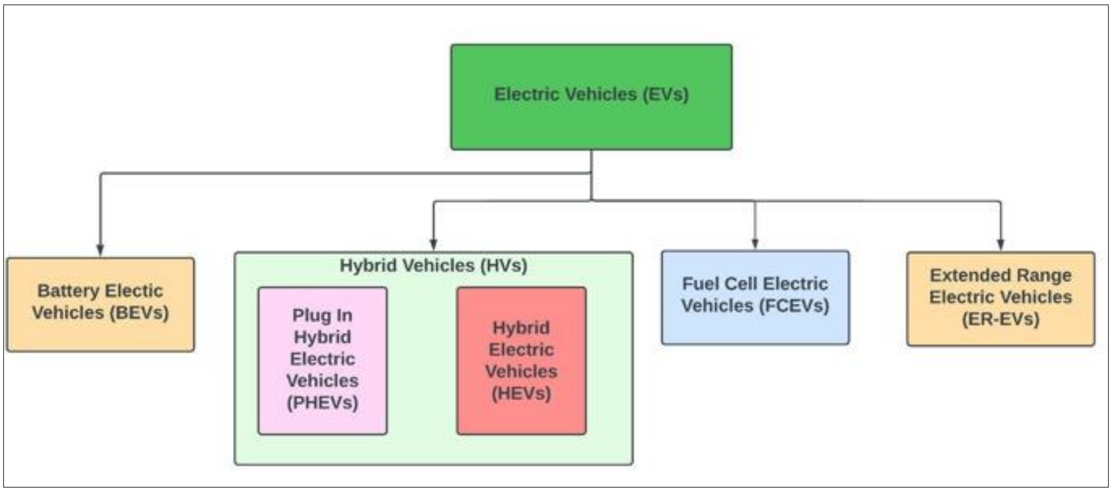

Figure 1 Classification of Electric Vehicles

Wireless technologies have gained prominent growth nowadays in sending and receiving data which has reduced road traffic to an extent. Beyond 2020, mobile networks are required to support high volume of traffic which can be increased in the order of thousand folds compared to today experiences [57]. Current LTE network is not able to support this huge requirement due to its limited capacity. Exponential increase in user demands require a massive network beyond LTE which leads to the concept of 5G networks [58]. In order to meet user demands future Fifth Generation (5G) network is considered as prime solution to achieve high data rate, increased capacity, decreased delay, and increased Quality of Service (QoS) which are major limitations in Long term Evolution (LTE) networks. 5G network is integrated with two significant technologies such as "Multiple Input Multiple Output (MIMO) and millimeter wave (mmWave)". Generally, 5G network is one unified global standard that follows key terms such as Worldwide Wireless Web (WWWW), wearable devices with AI capabilities, support multiple access technologies. Machine type communications are supported by 5G network which impacts the growth of Internet of Things (IoT). Through 5G machine type communication every device in IoT smart home, vehicular network, healthcare, etc. are able to communicate with each other without loss in originality. Thus, 5G network plays vital role in IoT technology also. In 5G networks, operators are allowed to deploy the network in more convenient and comfortable manner in the form of small cells (pico cells, femto cells, remote radio unit, and so on) that are connected to centralized base station with massive MIMO technology [59]. Deployment of small cells results in high data rate, efficient spectrum usage, energy saving, cost effective, less congestion, and easy handoff.

Here femtocell communicates within 10 to 20 meters to support few users, picocel communicates up to 200 meters in order to support 20 to 40 users. Microcell refers to a 5G small cell which has communication range up to 2 kilometers and enables more than 100 meters in the network while the communication rage of macrocell is 30-35 kilometers and supports multiple users [60]. Fifth generation network is involved with following features: (i) supporting 10 to 100 numbers of connected devices, (ii) achieving 100 times higher data rate per volume area, (iii) providing latency about 1 millisecond, (iv) providing 9.99% availability, (v) realizing 100% coverage, (v) minimizing energy consumption, and (vi) seamless integration of the current wireless technologies. But still, the transportation system cannot be completely substituted by means of online environment. Vehicle systems are essential in several other applications.

2. Review Paper Organization

2.1. Motivation

Major motivation in this field of electric vehicle in communication is the deployment of extensive use of electric vehicle recently. Apart from its numerous advantages, it possesses several challenges too such as requirement of heavy metals for EV body. Several “energy transition metals (ETMs)” encompassing “iron, copper, aluminium, nickel, lithium, cobalt, silver, platinum and rare earth metals” are estimated to face market pressure as creation of low carbon energy technology intensifies. Advancements with respect to material efficacy and recycling are not found to be appropriate enough to meet increasing demand for energy transition metals. Social and environmental level allegations of suggested rise in “ETM” extraction are hardly acknowledged in energy transition schemes. Trade-off projections could typically not distinguish between the point of extraction and residual supply chain. These factors are the major motivation factors which could assist with electric vehicle deployment.

2.2. Paper Organization

The current review paper is organized as follows. Section I labels the introduction part which includes background of the study, scope of research, problem definition and purpose of the study. This section will give a background of study, scope of research, problem definition and purpose of the study. This section will provide an overview of autonomous vehicles and its vital characteristics. The need for effective methods on autonomous vehicles will also be discussed. Motivation, paper organization and contribution is also mentioned. Section II is the comparison of existing methods on autonomous electric vehicle communication networks. Section III mentions related works. This section will discuss various existing works on Autonomous driving vehicles. The diverse techniques employed in existing literature for solving challenges in electric vehicles will also be reviewed. Section IV is the algorithms and architectures used on autonomous driving which discusses the popular technologies, algorithms, and architectures used on Autonomous driving has been discussed. Section V is the challenges which mentions challenges faced in the real-world and Section VI is the conclusion part which presents the findings of the study, and some suggestions will be recommended for future work.

2.3. Contributions of Survey

The major contribution of this research work includes the significance of electric vehicles, its deployment in several applications such as energy domain, communication, and autonomous electric vehicle by means of IoT or blockchain based terminologies. The electric vehicle utilization has been increasing each day and hence, this survey provides valuable information about electric vehicle usage, its applications, and challenges.

3. Comparison of existing methods on autonomous electric vehicle communication networks

Electrified way of transportation technology is seen as unique as it is one among the techniques which is mobile, accessible publicly and it could be integrated to electric grid system [13] [61].

3.1. Review on Several Communications Networks

V2G topic is mainly not so far away from electric vehicle, the V2G technique presented as system could support a controllable, duplex electrical energy among electric vehicle and electrical network. As an average, a huge amount of vehicle remains parked a long time per day on the same reserved place. V2G system assists with idea of using the batteries of those electric vehicle during these long parking areas. Moreover, it stores the produced energy at times when the demand is found to be lower than electricity and reinjects it to network when demand is found to be higher than produced quantity [14].

The automated vehicle (AV) systems are the electronic kind of systems in which, they affect the longitudinal and lateral movement of any vehicle system such as acceleration, geo-location, braking and sensing by means of cameras, sensors and radar which could demand the degree of precision [62]. They are found to be nuance and complex in nature which requires an integrated kind of relationship among the hardware and software. Here, the vehicle software is as required if not more important, than the vehicle hardware. Also, the AVs could not necessitate connected vehicle technology to operate as they would be capable of navigating the road network in an autonomous manner [15].

A cloudlet based intelligent agent was suggested for energy crowdsourcing from the autonomous electric vehicle (AEV). The prevailing energy crowdsourcing system mainly concentrates on load shedding and cost saving, but it lacks incentive models for strategically behaving agents [63] [64]. Here in proposed model, the crowdsourcing agents residing at edge network communicates with AEVs in stimulating them to take part in assisting energy to grid on peak time intervals [23].

A “deep reinforcement learning based EMS system” is suggested as it could learn to choose actions in a direct manner from states without any prediction or predefined rules [65]. In [24], a “DRL” based online learning environment is suggested where it is significant for applying “DRL” algorithm in “HEV energy management” under the diverse range of driving conditions. Simulation has been done by means of MATLAB. The results attained validated the efficiency of “DRL” based EMS system compared with rule-based EMS with respect to fuel economy. Here, the online learning architecture was seen more effective and proposed approach here ensures optimality and practicability of HEVs [66] [67].

3.2. Review Explore on Autonomous Transport Systems Communication Networks

In intelligent transport systems control and design, the speed forecasting possesses several applications particularly for safety and road efficacy-based applications [70]. The electromobility specifies most dynamic way of parameter for effective online in-vehicle management. The vehicle’s speed forecasting is moreover a difficult task as its estimation is closely related to several features which could be mainly classified into two groups such as endogenous and exogenous [68] [69].

The endogenous features could assist the electric vehicle’s characteristic features where the exogenous indicates the surrounding context like traffic, weather, and road conditions [72]. A speed forecasting method was introduced based on Long Short-Term Memory (LSTM). Here, the LSTM model training is acted upon dataset collected from traffic simulator depending on practical data which specifies urban itineraries [71]. Here, the proposed systems are considered for univariate and multivariate systems, and it is assessing with respect to accuracy for speed forecasting [25]. An energy management of HEV system. Markov Decision Process is suggested in [26].

A novel means of velocity profile prediction technique is introduced depending on specific CPS model in which there are three major efforts mentioned. At first, a CPS is built which is suitable for velocity profile estimation. Then, the hybrid velocity profile prediction is suggested based on exclusive CPS structure. The HVPP method could accomplish velocity profile estimation in accordance with employing diverse control units in CPS. After that, a case study is executed in plug in hybrid electric vehicle to examine effect of CPS based service. Attained outcome of case study indicates that HVPP could enhance fuel economy of PHEV [27].

4. Related Works

In previous years, there has been huge advancements in numerous aspects which are mainly related to production of electric vehicles and its deployment [16]. As a result, several research works also focused on electric vehicles which caused emergence of new job opportunities and proposals which were related to electric vehicles [38]. Here, a short compilation of the relevant topics associated to Electric vehicle is addressed with the support of previously available literature on electric vehicle utilization [6]. Some researchers accomplished evolution of electric vehicles throughout the history and provided classification as per the manner in which they have been designed [73] [74].

“Research in [31] reviewed the history of electric vehicles from creation from nineteenth century till present. Additionally, they carried out classification of vehicles as per their powertrain settings. The research analyzed impacts of charging electric vehicles on the electric grid. Similarly, the research in [32] suggested the effects that electric vehicle could produce in the required productivity, efficiency, and capacity of electric grid [5]. Moreover, the economic and environmental impacts of electric vehicles were reviewed. [33] presented survey of charging methods of electric vehicle and analyses their effect in power distribution systems. Research work in [34] presented a common prophecy about electric vehicles and renewable energy systems”.

They explicitly concentrate on solar and wind power and presented a set of works that were categorized into 3 main categories: (i) those researches which study the interface between EVs and the renewable energy sources for decreasing the energy cost, (ii) those research works motivated on cultivating the energy efficiency, and (iii) the research proposals that were generally looking for reducing emissions [36] [37].

On the other hand, [35] examined the prevailing studies about the environmental control of the "Hybrid Electric Vehicles (HEVs) and the Battery Electric Vehicles (BEVs)".

4.1. Recent Works on the Battery Modelling – Review Articles Survey

"Particularly, they present works concerning battery modeling, charging and communications standards, as well as driving outlines. Lastly, they showcase a set of diverse control approaches to accomplish EV fleets, as well as mathematical systems for its modeling [39]. [40], presents a set of employed systems for solving diverse complications that are associated with the charging arrangement of PHEVs and BEVs [75]. Furthermore, they assess the diverse charging systems in different environments, such as domestic garages, apartment complexes, and shopping centers. Since the substantial EV deployment will familiarize negative effects on the surviving power grid, some research works review the different problems and the possible opportunities that EV integration in the smart grid could support. [31] studied the impacts of EV deployment from the perception of vehicle-to-grid technology, and particularly for modifying the renewable energies intermittency. [41] discussed all of the features connected to EV charging, energy transfer, and grid integration with distributed energy resources on the Internet of Energy (IoE. [43] reviewed current innovations in Big Data analytics to allow for data-driven battery health assessment. More precisely, they organize them with respect to viability and cost-effectiveness, and discourse their advantages and boundaries. [44] suggested one step further and proposed a machine learning-enabled system that is based on Gaussian process regression (GPR) to expect lithium-ion batteries aging. Finally, other methods as an alternative explored progressive fault diagnosis system, as battery faults could possibly cause performance degradation [45] [43]".

5. Algorithms And Architectures Used on Autonomous Driving

Driving cycle data possess significant influence on fuel economy of "HEV" and at present, the conventional "EMS" is mainly based on standard means of driving cycles [21]. Here, the actual driving cycles are diverse, and there are transformations between the actual driving cycle and standard driving cycle which could result in the fact that fuel economy of classical EMS could not reach theoretical optimum in practical means [76] [77]. Alternatively, owing to the uncertainty and complexity of traffic conditions, the classical EMS are not adaptive enough to assist with diverse traffic conditions and particularly for urban areas, there exist severe uncertain elements like traffic flow conditions, traffic lights. Here, gaining real time traffic information is necessarily important [10].

For modeling dynamic changes of vehicular cannels and optimization of vehicle routing and traffic flow, the machine learning methods would be most appropriate. The machine learning systems are integrated into RSUs which would predict the traffic patterns by collecting information regarding vehicles. The machine learning would assist intelligent IoV routing protocol with criminal information for highly dynamic environment [9].

The involvement of UAVs could establish less delay, but it could considerably reduce the lifetime of network as UAVs are battery powered energy limited devices. This could be attained by performing two major phases such as route discovery and route selection [11].

With regard to in-vehicle technology, the automotive vehicles would not lead to an effective autonomous driving and these automotive vehicles require additional external support for computing tasks. Additionally, effective and safe mobility might not be possible if automotive vehicle could behave in an individual manner. Here, a cooperative environment is required which involves communications and the AVs must be communicating among them, along with infrastructure including cloud, pedestrians, mobile phones and other personal devices, becoming connected autonomous vehicles [78]. All of these information exchanges were globally termed as "V2X communications". Establishment of robust, powerful, safe and reliable communication network still remains a concern and this network might be capable of transmitting huge amount of data at high level speed and low latency in all states without any interferences [19] [20].

5.1. Modelling Dynamics Review

In automated electric vehicles, the transparency and safety are equally important in which, blockchain based technique is more adequate. During the vehicle movement from one place to other, the vehicle details are attained by means of IoT devices and gets stored in blockchain network. Hence, if intruders could attack or hack any IoT objects for gaining benefits, the user or vehicle present in network are aware of data registered under that particular compromised IoT device [79]. Even though several automotive vehicle-based communications have been discussed in several research works, security of those applications are lagging in research [17]. Here, in IoT based blockchain framework, each automated vehicle is registered into network before its given access. Then, the relevant information of both vehicles and IoT devices were entered to ordinary database and stored in blockchain to track every activity of both entities.

The block chain is mainly capable of assisting three main risk factors while building a trust network among intelligent vehicles without the central control authority. This could protect the security and privacy against cyber-attacks and guarantees resilience under the unpredictable failure or attack on vehicular cloud network. The block chain technology is based on peer-to-peer connections which could allow intelligent based vehicles to communicate with one another without any intervention of third-party authorities. A huge mass of vehicle nodes ensures the resilience of block chain networks and even some nodes are unavailable owing to infected nodes with malicious software or those under cyber-attack. Suitable block chain will be still accessible to the vehicles. Even though if some of the nodes remains offline or under attack, the block chain could make vehicular network function as usual [12].

The wireless electric vehicle charging is mainly based on inductive power transfer technique, which could transfer power between two coupled coils, such as a primary coil at wireless charger connected to electric grid and secondary coil situated at EV. There exists reasonable means of air gap among them. In these near field means of charging technique; the transmitting coil of wireless charger creates a magnetic field which could transfer energy by means of induction to an adjacent receiving coil of EV [80]. Some fraction of the magnetic flux created by transmitting coil which penetrates receiving coil might contribute to power transfer. Here, the transfer efficiency mainly depends on coupling between the coils and their corresponding quality factor. There exists two major inductive power transfer such as static and dynamic. Since the wired charging would be impossible while EVs are on motion, hence the wireless power transfer might be the exclusive solution for dynamic or quasi-dynamic charging [18] [22].

An advanced “fitness-ant colony optimization (FACO)” is suggested for EV route optimization in communication which is mainly segregated into two phases such as conditional route discovery and range sustained traversing. The conditional route discovery could support possible levels of visiting paths to DPs in a probable manner. The fitness function could optimize the visiting plan to retain rc<t.

5.2. Distance Measurement Algorithm Equations Reviews Explore

In a traditional “ACO” system, the ant agents visit the destination in multiple paths, and they visit different neighbors to reach destination and number of neighbors defines ant agents. Here, different from traditional “ACO”, fixed slots of ants are deployed to discover routes to destination. Destination mentioned here is longest DP, the routes to the DPs are discovered in accordance with its location. Major objective to be attained in the route discovery is the minimum delay and hence, the major phenomenon of ants is established to meet condition of attaining minimum delay.

Let EV travel from one DP, such as i to k, the time of travel (ttv) is predicted with the help of equation,

$$t_{tv} = \frac{distance_v^t}{EV_v^t}$$

Where,

$distance_v^t$ and EV_v^t denotes the distance and velocity aspect of electric vehicle in router v at a time interval, t. Total amount of time taken for an electric vehicle for visitng all links including regular, and demand are predicted to be as,

$$\Delta t_{tv} = \sum \square_r \sum_{i=1}^{n} \frac{distance_r^i}{EV_v^i}$$

Where, n is the time period mentioned for the EV to visit all the routes.

The probability measure that an ant visits DP j after leaving DP i is expected as,

$$\rho_{ij}^{distance}(t) = \frac{\left[\tau_{ij}(t)\right]^{\beta} . \left[\eta_{ij}\right]^{\gamma}}{\sum_{j \in r} \left[\tau_{ij}(t)\right]^{\beta} . \left[\eta_{ij}\right]^{\gamma}}$$

Where, τij is the pheromone absorption rate in the route (i,j) and ηij is the heuristic value for ttv.

β and γ are the balancing constant and β + γ = 1. The rate of pheromone absorption declines with varying time interval in a route (i,j) that is assessed as,

$$\tau_{ij} = (1-\lambda)^{*} \tau_{ij} + \sum_{r=1}^{b} \Delta\tau_{ij}^{r}$$

Where, (1 – λ) is a pheromone declining rate,

$\Delta\tau_{ij}^{r}$ is the pheromone quantity present in the route (i,j), most recently updated by the bth ant. Unlike in traditional ACO method, the low pheromone ant pursues an advanced pheromone ant if there is a collective intersecting DP for two or more ants [29].

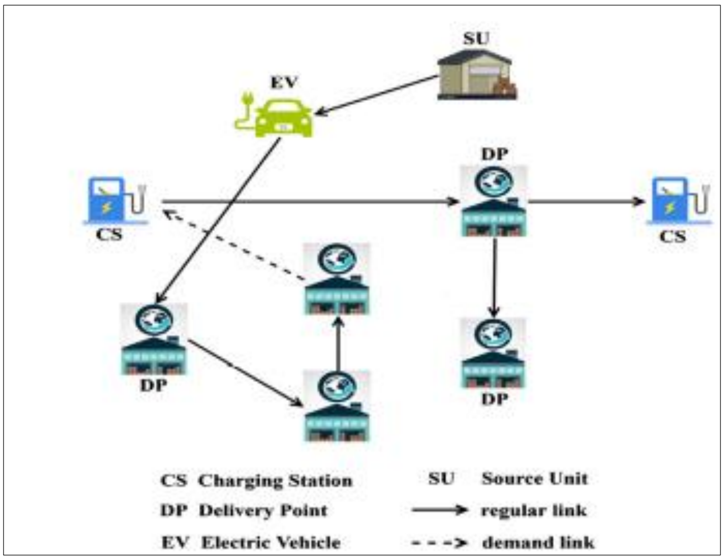

Figure 2 Electric Vehicle (EV) State Transition Diagram

To assist the safe driving of future vehicles and meet entertainment requirements of passengers, it is quite essential to suggest future 6G vehicular intelligence system. In [30], the networking, communications, computing, and intelligence is discussed, and the future technological developments are suggested with its challenges and research directions.

6. Challenges

The electric vehicles possess a major challenge in electric utilities and the extreme integration of electric vehicles into distribution network could influence load profile, distribution system component capability, voltage and frequency disparities, power loss and the stability concern of distribution grid [2]. Even though the autonomous electric vehicle communication could be advantageous, there exists existential issue in driverless vehicles. 100% service availability cannot be assured as in today or in coming years since human interaction is mission critical. Moreover, it has data protection problems and high-cost implementation.

Moreover, one such major challenge in deployment of electric vehicle is that it could increase mining activity as EV requires metals. In mining-based industries, the projects are accumulated in numerous categories which could satisfy diverse areas of function. Mining based functions, engineering, and information management launches projects from timely manner to assist continuous production. Addition of PMOs in huge organizations, particularly mining organizations has predominantly supported to the success rate of projects. Owing to the significant capital investments of Mining projects, a significant number of these, even in developing economies, is driven by cash flush major who are domiciled in developing countries and ESG principles are predominantly drawn from sustainability practices followed in developed countries. Yet, ESG factors in mining projects are highly context-specific and developed countries' ESG practices may look good on paper but may be of limited use in emerging economies. As such, the key interest of this article is to enrich our understanding of the competing ESG factors, their contexts and the trade-off analysis required to build resilience and capacity for the sustainability of mining projects that will support the energy transition. An integrated context driven ESG approach is considered relevant in balancing all three aspects of environmental, social and governance simultaneously and evenly to avoid feedback loops. ESG are a set of many non-financial activities in a cogwheel, all of which must be completed for the product to have full value. Furthermore, sustainability in mining has become a more relevant field of study in that while mining is expected to provide large quantities of energy transition metals, it is inherently “dirty” by design, creating substantial environmental impacts through the excavation of the ground with complex decisions such substitution of land use, displacement of communities when processing millions of cubes of material each year which generate large quantities of waste and using huge quantities of water.

The mining actions could alter the host environment and tend to exacerbate pre-existing vulnerable actions, particularly in commands where governments are unable, or disinclined to protect against severe social and ecological externalities. The extraction of minerals has mainly contributed to environmental degradation, displacement, violent conflicts, human rights violations, and other adverse effects. Management of obstacle risks that supplement energy transition metals extraction stays at core of just transition, which is a transition intended to report climate change while concerning rights of workers and communities and defending environs. Heavy competition might arise regarding freshwater accessibility among mining industry and other water users. In mining, ESG factors have complex motivational structures, especially in developing economies and they tend to tease out diverse economic, government, and community forces that operate at multiple levels to produce damaging or perverse outcomes. As an outcome, the region has traditionally produced huge social and environmental legacies. The focus on technical elements in the planning and execution of mining programmes have been found short in addressing the significant complexities that lie outside across the fence of the mining operations; complexities that generate risk to people and the environment, as well as risk to the resilience of future projects, especially ETM projects that will support the global climate agenda. Therefore, novel approaches are needed for these projects in inflammatory locations to be brought to market and be resilient in adding value to the world.

7. Conclusion

Considering recent advancements in the field of autonomous vehicles and associated communication technologies, it is critical to propose industry standards and safety mechanisms in communication networks. Keeping in mind the high-fidelity data that is generated and the possibility of exposure of data in the event of cyber-attacks, it is pertinent that robust, resilient communication networks need to be developed. The communication topology in a vehicle can be seen from different perspectives – information/signal transmission can happen via hard wired signals, local interconnect network (LIN), controller area network (CAN) and lately ethernet. Based on the speed of communication they can be viewed as long term evolution network (LTE) or 5G networks. Further they can be termed as wired or wireless communication networks.

Each of these classifications have a rationale behind their consideration – range of communication, fidelity, security et al. A thorough trade-off analysis considering needs to be performed while choosing a network topology during initial stages of system architecture design.

This paper surveys communication networks and recent trends in-vehicle communication from an autonomous electric vehicle perspective. There lies future scope in improving the security of message communicated by using real-time fault detection mechanisms and plausibility checks. Currently, several communication topologies propose redundancy in channels as means to ensure reliability. Alternate cost-effective means can be studied to provide plausible communication.

Compliance with ethical standards

Acknowledgments

We would like to thank authors of references we listed for this review, providing some outstanding insights on concepts for making review feasible. We would also thank the reviewers of WJARR journal for inputting their valuable time and assisting for potential fixes.

Disclosure of conflict of interest

No conflict of interest.

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