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Heterogeneous LPWAN Communication for Electric Vehicle Charging Infrastructure

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***Abstract**: Many countries worldwide are set to include Electric Vehicles (EV) as a prime element in transportation policy owing to political polarization to combat climate changes. Circumstances are conducive to a sustainable mobility paradigm and have accelerated the adoption of EVs. The situation demands the deployment of charging infrastructure at a faster pace. Smart Grid provides the pervasive support for the deployment of charge stations. But the charging infrastructure should scale beyond the frontiers of metropolitan geography. The paper proposes a heterogeneous network to support mobility to EV users utilizing the paradigm of the Internet of Things (IoT). A heterogeneous ad-hoc network of Low Power Wide Area Networks (LPWAN) and mobile data communication is proposed to support mobility and scalability of the infrastructure. The proposed ad-hoc communication infrastructure utilizes LoRaWAN, a promising LPWAN technology characterized by a long-range at a narrow bandwidth. LoRaWAN employs Chirp Spread Spectrum (CSS) in its physical layer. The paper peeps into standards and protocols supporting Smart Grid and EV charge infrastructure. An SNR characteristic of LoRaWAN is simulated for suitability and Hardware for communication node is proposed.*

***Keywords:** EVCE, Heterogeneous network, LPWAN, LoRaWAN, Smart Grid.*

I. INTRODUCTION

The decade has shown favorable circumstances for electric vehicles to enter the mobility sector. The factors include [1].

1. The Climatic change created by global warming has set the need to reduce fossil fuel consumption. The global concern had benchmarked reduction in Green House Gas (GHG) [2] emission by 33 to 35% below 2005 levels by 2030.
2. Advancements in renewable energy especially solar energy harnessing technologies have shown a drastic reduction in cost popularizing low carbon clean energy through inexpensive grids.
3. Rapid urbanization demands substantial enhancement of transport infrastructure leading to pollution and congestion.
4. Mobility is digitally enabled through connectivity. This has created better utilization of transportation infrastructure. Utilizing digital technology, EVs can be benefitted from lower operational costs to offset a relatively higher cost of ownership.
5. Amelioration in battery technology has led to faster charging, higher storage densities, and longevity. Combined with advancements with electric drives, these improvements in battery technology have improved efficiency and performance of EV Charging Equipment (EVCE) at a reduced cost.

As a result, developing and developed economies have accepted electric vehicles as a policy to lower carbon emissions along with the cost-effectiveness of mobility. When EVs multiply in volume, sufficient deployment of charging infrastructure needs to be ensured. Charge stations set in garages or parking lots alone are not sufficient. For long commuters availability of charge stations in all vicinity is critical. Even in cases when charging is not critical, many drivers do frequent charging due to anxiety of range which shortens battery life [3].

Power Grid in the urban scenario is developing at a faster pace to accommodate transformations in renewable energy utilization. The power grid integrated with Information and Communication Technologies (ICT) transforms itself into Smart Grid. A smart grid integrates renewable energy sources and promotes small scale production and dissemination of renewable energy in an urban scenario. Unless renewable energy sources are effectively utilized for EV charging, there will not be any footage in enhancing carbon credit. The adoption of a pervasive communication network integrates discontinuous energy production based on demand and response enhances the stability of the grid.

The discontinuous and intermittent nature of energy production through solar and wind has to be adequately managed. Peak production during noon-time can be effectively utilized only if the generated power is stored. EVs can be considered as a distributed energy storage facility. The fluctuating nature of load caused by EV charging, the load has to be managed without affecting the quality of power. This proposes a requirement of an ad hoc communication facility with a cloud computing backbone for handling distribution, levying, and interaction with grid users. Additionally EV users can be offered ancillary services to effectively manage the charging time. The paper proposes a heterogeneous network of Low Power Wide Area Networks (LPWANs) as a paradigm of the Internet of Things (IoT) and mobility of LTE or 5G as the communication backbone for LP charge stations.

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The LPWAN provides a star of star network with gateways for exchanging information with the Cyber Physical System for the units of charge, availability of charge slots whereas the later provides communication interface for the user for locating charge stations, availability of charging slots, updated tariff information and connect to payment gateway.

II. RELATED WORKS

Paper [1] presents the policy framework in the Indian scenario to promote zero-emission vehicles. The policy framework aims reduction in primary consumption of petroleum products in the transport sector through the adoption of clean energy technology. EV technology along with reducing carbon emission in urban inhabitancy encourages the adoption of cutting edge technology facilitating employment in the growth sector. The framework presents two approaches for EV charging.

1. Battery swapping technology.
2. Providing an ecosystem using clean energy for the fast charging of batteries.

Though the aforesaid provides convenience to the users by providing quick service, it cannot be substituted for charge stations. Swapped batteries should be kept charged for later usage. The policy suggests creating required infrastructure every kilometer in dense areas making utilization on EVs economically viable. The paper mention required standards for charge station including the range of power and voltage required by EVs depending on the capacity of vehicles, EVCE output requirement as AC or DC depending on the onboard charger, type of socket, communication protocol between vehicle and EVCE.

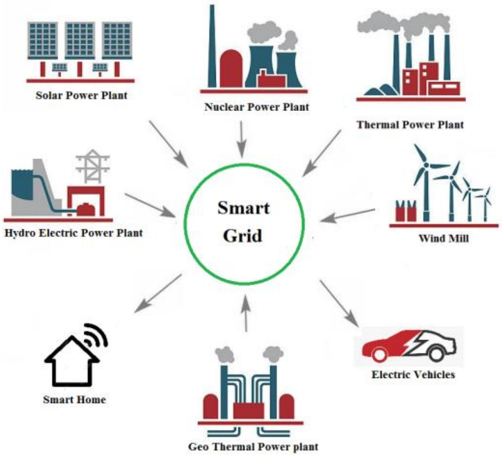

Fig. 1. Smart Grid infrastructure.

Global energy demand is set to grow by 37% by 2040. The depletion of nonrenewable energy sources and the ever-increasing demand for energy set no alternative other than harnessing renewable energy sources such as solar, wind, hydro, geothermal, biomass, etc [4]. Advanced technologies to coordinate reliable and secure energy distribution are required to be adopted. The advent of Smart Grid (SG) set a new paradigm in energy distribution. The behavior and action of stakeholders in the energy supply chain are well coordinated by SGs for efficiency and security. The success of SGs lies in seamless interaction of the grid infrastructure as a physical power distribution system, information access, control, and the cyber processing system. The Cyber-Physical System (CPS) serves as the backbone for coordinating the SG. The physical system which includes power distribution and production infrastructure needs to establish connectivity to update CPS with dynamic parameters. The need for an ad hoc communication network for transferring dynamic response for real-time processing and decision making is emphasized in the paper [4].

The article [5] proposes a heterogeneous communication to support the communication requirement for SG. An end to end integration of protocols of heterogeneous nature using ubiquitous sensor networks architecture establishes interoperability with next-generation technologies. Proposed through this technology, is a blend of wired and wireless protocols. Wireless sensors communicate through IEEE 802.11s standard whereas Narrow Band Power Line Communication (NB-PLC) transfers data to substations Ethernet. The architecture proposed includes LTE, broadband PLC, and WiMax integrated into the network.

SG builds the core electrical infrastructure for charge stations. Referring to as Grid to Vehicle (G2V) flow as EV charging, [6] proposes for peak demand functionality of Vehicle to Grid (V2G) power transfer enhancing grid quality. V2G allows EVs connected to SG to feed electric power back to the grid. The functionality as power storage eases peak demand of the grid. This facility can be extended between EVs to share power.

Table- I: Proposed charging alternatives for an EV user.

Parameters	Alternative services			
Type of charging	Conductive (wired)	Inductive (wireless)	Battery swapping	
Phase	1 phase	3 phase	EV dedicated	DC charging
Power	Low <3.7 kW	Medium 3.7 – 22 kW	High 22 – 50 kW	Very high > 50 kW
Domain	Private	Public	Semi public	
Billing	Free	Fixed monthly	Per charge	Per used resources
Information	Stand alone	Uni directional	Bi directional	

Electro Mobility Service Provider (EMSP) is an emerging business model in the EV ecosystem [7]. The mobility services offered to the customers include search, finding, routing, charging and other services. The business entity provides EV charging services irrespective of the location whether it is at the workplace, home or at any location. The EMSP maintains a database of the portfolio of EV users. The business model proposes a charging service operator which is part of the supply chain operates EVCE and is responsible for the management, monitoring, controlling and maintaining the infrastructure. The EMSP maintains business to business (B2B) relationships with the third parties who are small scale nonrenewable energy harvesters utilizing limited rooftops of their dwelling. The article also proposes a Market Place Operator which is a virtual business model for mobility services.

The virtual services are available through the internet in a cloud computing environment. Table I lists the charging alternatives provided to the users.

Paper [8] proposes Open Charge Point Protocol (OCPP) and Open Smart Charging Protocol (OSCP) promoted by Open Charge Alliance (OCA). OCPP is a SOAP-based protocol. OCPP 1.5 can handle up to 10 charge points. Through interdependent research work for dedicated protocols for handling EV charging infrastructure is in progress, a consolidated approach is envisaged.

III. SMART GRID INFRASTRUCTURE – STANDARDS AND SPECIFICATIONS

Mentioned in the previous session, EV charging infrastructure comprises a power system within the SG framework, CPS and communication support system. IEEE P1547 standard defines interconnected and distributed power resources and IEEE 2030 defines interconnection within the grid [9][10]. These standards are set by IEEE Standards Coordinating 21 (SCC21). The committee oversees developments in dispersed power generation and storage. IEEE 2030 and 1547 recognize interactions of power, information, and communications within SG. The standard perceives the dynamic nature of the Powers System (PS) and proposes mechanisms to ensure a balance between generation and delivery.

A. IEEE 1547 standard series

The standard comprises seven complementary classifications based on the root 1547. First published in 2003, the version is reaffirmed in 2008. The standard interconnects resources of the distributed electric system. The complementary standards are [10]

- IEEE P1547.1 defines standard test procedures in conformance with 1475-2003. The procedures confirm the stability of components and Distributed Resources (DR) when interconnected with PS.
- IEEE P1547.2 provides technical information characterizing technologies applied for DR, issues related to interconnection, tips and thumb rules pertaining to project implementation.
- IEEE P1547.3 specifies the interoperability of DR within a PS. Functionalities, control and information transfer within an area PS are defined in the standard.
- IEEE P1547.4 devised in 2011 proposes “intentional islands” referred to as micro grids. The popularity of micro grids lies in the proposal for local generation and storage of power which is a significant factor in the utilization of SG for harnessing nonrenewable power and usage for EV charging.
- IEEE P1547.6 recommends procedures for interconnecting DR with the secondary distribution system. These recommendations facilitate setting EV charge Stations at secondary distribution systems that are not coming under the purview of SG. This standard identifies communication and control guidelines for such secondary systems.
- IEEE P1547.7 describes the methodology for promoting engineering studies for enhancing the interconnection of DR. The criterion led to the expansion of interconnections without compromising the quality of the grid.
- IEEE P1547.8 proposes flexibility in the design and strategic expansion of the grid.

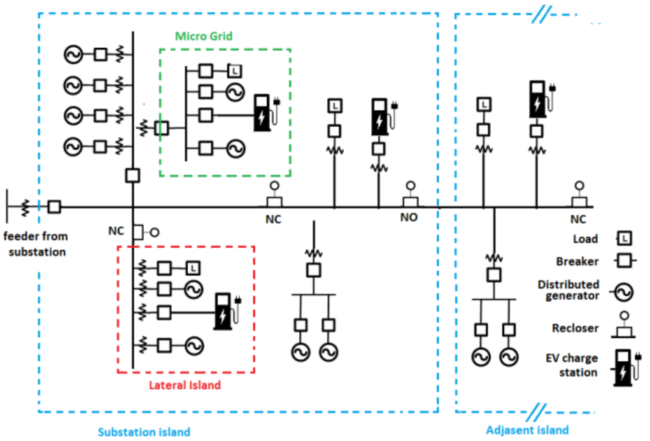

Fig. 2. IEEE 1547 architecture.

B. IEEE 2030 standard series

IEEE 2030 standardizes the interoperability of ICT and electrical infrastructure. There are three complementary expansions of 2030.

- IEEE P2030.1 specifically addresses EVs and support systems. P2030.1 provides an information base for addressing vehicles and infrastructure in the support system.
- IEEE P2030.2 covers hybrid and discrete energy storage which are integrated with SG.
- IEEE P2030.3 standardizes test procedures for energy storage in SG.

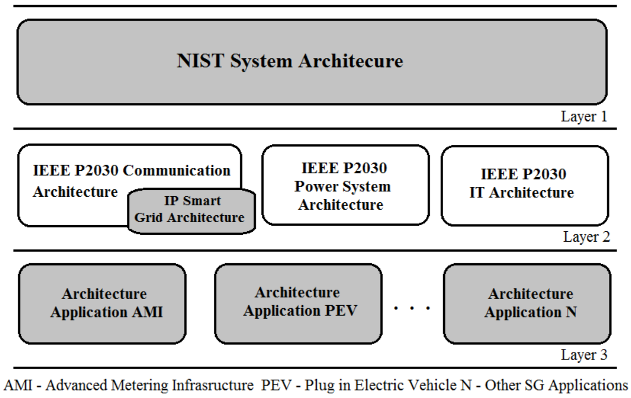

Fig. 3. Three Layer Smart Grid Architectural model.

IV. STANDARDS AND PROTOCOLS SPECIFIC TO EV CHARGING INFRASTRUCTURE

A. EV to EVSE communication

The communication in EV charging infrastructure happens in multiple instances. Primarily it happens between vehicle and EVCE where information regarding billing, authorization, battery condition and quantity of energy transferred [11] are shared.

The Society of Automotive Engineers (SAE) has defined communication standards for the vehicle to communicate with EVCE. There are standard test procedures performed every time the EV is set for charging [12]. SAE J2931: standardize communication between EV and EVCE. SAE J2931/1 offers Power Line Communications (PLC) as a protocol for that matter and SAE J2931/2 put forward a definition of the physical layer for the protocol. SAE J2836/1 handles the time of usage, updated pricing. Standards for fast charging under IEC 61851.23 defines standards for grid communication and ICE 61851.24 for communication between EVSE and EV are defined by the International Electro-technical Commission (IEC).

B. Power Grid to Energy Management Unit (EMU)

A perfect understanding of energy prices helps customers for optimum usage of EVCE. The concept is equally important for load balancing of the grid to ensure grid stability. Optimal discussions can be made only with an IT-enabled system. Energy Management Units (EMUs) enables customer interaction for optimal energy usage. Home Area Network (HAN) connects EVCE to EMU. Popular protocols to support HAN are suggested as Zigbee, Wireless Local Area Network (WLAN) operating under IEEE 802.11, or LTE network. Standards propose (PLC) as an alternate protocol for the grid to EMU interaction.

C. EV to Data Center

Customers need to communicate with the data center for locating the nearest EVCE, for information, pricing, registering, and payments. The paper proposes the usage of data services of LTE or 5G mobile networks to connect to the user for the purpose. An application installed in the mobile or the operating system of a connected car can provide the interface.

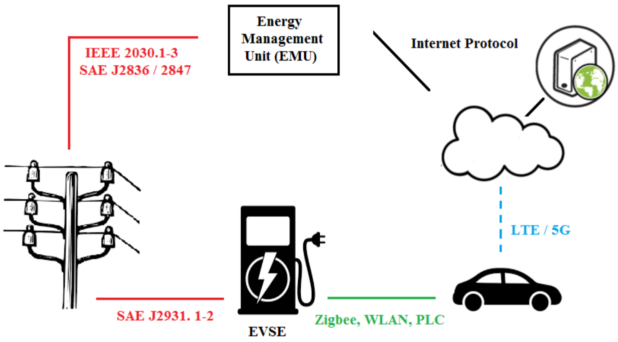

Fig. 4. Conventional EV charging Infrastructure.

V. PROPOSED HETEROGENEOUS COMMUNICATION INFRASTRUCTURE

Conventional SG proposes as the protocol for the interaction of EVCE, grid, EMU, and CPS. The recommendation suggests 3 – 500 kHz, narrowband PLC to handle data up to 10 kbps rate [13]. Though the rate is quite sufficient for data transfer within the grid, the communication protocol is less reliable within the environment due to the enormous possibilities of EMI and harmonic interferences. In addition, most of the Medium Voltage Grids (MVGs) are least equipped for this communication and the behavior in the environment is unpredictable. There are many tests and simulations performed for characterization of the protocol, but the possibility for frequency signals to cross transformer is still a challenge. Attenuation due to the long transmission lines can lead to data loss adding on to the limitation of the protocol [13]. PLC for HAN is still not proved for success.

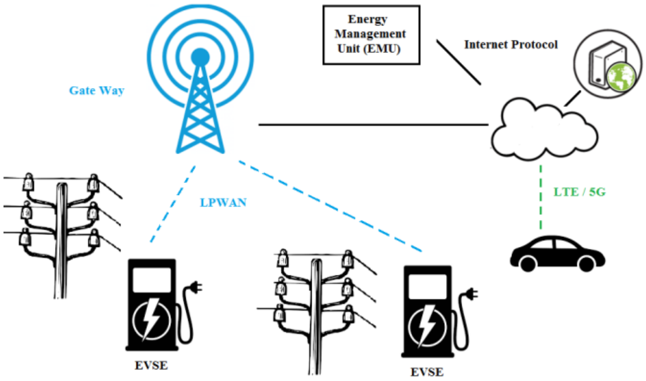

Fig. 5. Proposes LPWAN – LTE / 5G Infrastructure.

A. LTE / 5G proposition

The paper proposes a heterogeneous network of LPWAN and mobile LTE / 5G for EV grid interaction. The user communicates with EMU where the updated location information is passed which eliminates the need for any other protocol including HAN. Figure 4 refers to a conventional charge infrastructure whereas figure 5 shows the proposed. EMU allocates EVCE based on availability, connected load and distance from EV to the EVCE. Location information can be passed to EMU as a vehicle approaches the EVCE. This eliminates any need for authorization at EVCE as the EV cruising is trailed.

B. LPWAN for EVCE to EMU

Low Power Wide Area Network's (LPWAN) is an emerging communication technology characterized by long-range and low power consumption. Featuring a long range of 10 to 15 km provincial and up to 5 km in urban extent, LPWAN is ideally suitable for low bandwidth and low data rate communication [14]. Prominent technologies in the class are

Sigfox™

Sigfox operating at 868 MHz ISM band is an ultra narrow band communication protocol for sensor networks. Utilizing Differential-Binary Phase Shift Keying (DBPSK) using three random frequencies of the carrier, Sigfox provides a maximum of 100 bps bit rate. Most of the technical details of the protocol are unpublished due to the preparatory nature of the protocol. Since the European Union mandates a duty cycle restriction of 1%, the protocol can transmit only 36 seconds in an hour [15]. Thus the protocol restricts itself with the transmission of six messages per hour at 4, 8 or 12 payload. This makes the LPWAN technology least suitable for EV charging infrastructure.

Narrow Band -IoT (NB-IoT)

Operating at a bandwidth of 180 kHz, NB-IoT has evolved from LTE. The carrier is deployed within in guard band of LTE signals; the protocol is efficient utilization of spectrum. With a subcarrier bandwidth of 15 kHz, each device schedules its uplink with one or more cub carriers depending upon the required data rate [15]. Uplink bands are tightly packed to accommodate maximum data reducing the carrier spacing to 3.75 kHz. An improved version of 5G-IoT will provide faster network capabilities is under deployment [16]. Coverage limitations of 5G networks raise concerns.

LoRa

LoRa is a patented technology developed by Semtech Corporation, which forms the physical layer of LoRaWAN. LoRa uses Chirp Spread Spectrum as the modulation scheme, which is characterized by low power requirement, resilience to fading and Doppler effects. Excellent noise rejection characteristics of the modulation scheme make it most suitable for long-range narrowband IoT applications [17]. Operating at ISM band 863 - 870 MHz for EU, 865-867 MHz for India, 902-928 for the US, regional restrictions are applied to the usage. Though low power and Doppler Effect resilience are not critical to EV charging infrastructure, operating range justifies the choice as the communication protocol for EVCE to EMU. The protocol offers a range up to 15 km radius of the gateway in the provincial environment and can cover 5km in civic. Noise performance and range are factors of Spreading Factor (SF) which can be dynamically selected for the required range.

D. LoRa WAN for information exchange

The paper identifies LoRaWAN an LPWAN technology for the grid and EMU communication. As mentioned, CSS forms a modulation scheme for LoRa. Linear frequency modulation in the range $[f_{0,} f_1]$ of carrier makes up chirps. With f_0 and f_1 are the lower and upper frequency component of the spectrum, for a time period T the Band Width $BW = (f_1 - f_0)$. Utilizing the M- Array modulation scheme [19], the modulating symbols are circular shifts of the up chirps with the chip duration,

The CSS modulation of nth symbol is given as [19] [20]

$$f(t) = \begin{cases} f_1 + \eta(t - nT_c) & for \quad 0 \le t \le nT_c \\ f_0 + \eta(t - nT_c) & for \quad nT_c \le t \le T \end{cases} \qquad (1)$$

The linear frequency variation or slope is represented as

$$\eta = \frac{(f_1 - f_0)}{T}.$$

For the given bandwidth BW, which can be 125 kHz, 256 kHz or 512 kHz, for the centre frequency 866 MHz for EU or depending on may vary depending on region of operation, total symbols that can be encoded is 2^n where n is the Spreading factor (SF) and T_c the chip duration, the symbol duration T_s requires for encoding 2^n is given as

$$T_s = 2^n T_c = \frac{2^{SF}}{BW} \qquad (2)$$

The equation (2) suggests that for high SF, the time on-air is proportionally higher [18]. Where

$$SF \in \{6,7,8,9,10,11,12\}$$

LoRa uses up chirps for modulation symbols where are down chirps for demodulation. Down chirps are modulation in the range $[f_{1,} f_0]$. The simplicity of the modulation scheme is that encoding of up chirps is performed by multiplying the symbol with up chirps. This eliminates the need for any complicated processing system for the EVCE.

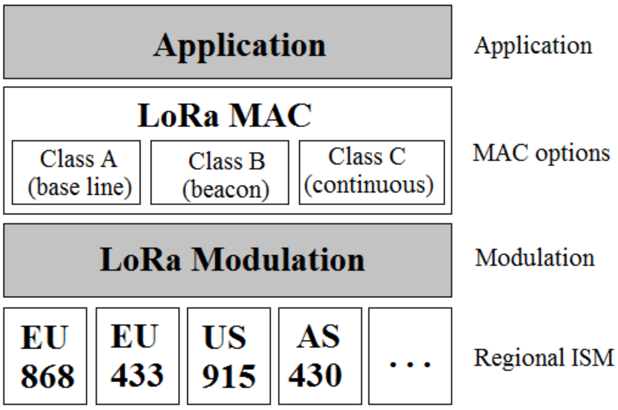

Fig. 6. LoRaWAN classes.

Symbols are encoded from data bytes to accommodate data handling limitation of SF based on equation (2) after whitening, adding header and CRC, error coding, interleaving, and gray indexing. At the receiving end, gray encoding, deinterleaved, error correction, decoding header, and CRC, and de-whitening are performed. Symbols are spread the entire spectrum as up chirps. Chirps maintain orthogonality with any other signals including those which are modulated at different SF. At the receiving end, band-limited signals are multiplied with down chirps of the same SF which maintains orthogonality with all other signals except for the same SF. Multiplication eliminates unwanted signals and an FFT performed identifies peaks corresponding to the symbol which can be retrieved decoding the peaks of FFT.

E. LoRa Device Classes

Class - A are bi-directional devices [21] where transmission slots are scheduled randomly. Pure ALOHA nature of protocol makes the device simple and power saving. The device is kept in sleep mode to save power until transmission required. The uplink messages are relayed and are received by gateways in the vicinity. In this class of device, downlink happens only during the acknowledgment cycle of the transmission. This class of LoRA device cannot be employed for EVCE. The device needs to be alerted by the Gateway whenever service is needed.

Class B [21] device locks to synchronized beacons that are transmitted by the gateway called “beacon lock”. Downlinks are scheduled by the server negotiating on the ping interval of beacons. The server maintains a queue of all payloads that are required to be transferred and scheduled for the free ping slot.

Class C [21] is an extended version of Class A.

These devices open the receive window always except when the device is transmitting.
These devices are energy-consuming and provide low latency communication. Class B devices are proposed as an ideal device for EVCE as operations are mostly server or EMU initiated.

F. Addressing

Identifiers are provided to devices for application by the LoRaWAN. The following addressing is applied whenever The EVCE logged on to the LPWAN

- Device-Unique hardware id (DevEUI) is a unique 64-bit address similar to the MAC id of TCP/IP.
- Device-Unique Address ID (DevAddr) is a dynamic 32-bit bit non-unique address provided or chosen whenever the EVSE joins a network.
- Application-ID (AppEUI) is a EUI – 64 is an application address unique to the application. AppEUI is stored in EVCE before the activation of the application.
- F-port identifies applications or services. Usage of Port-0 is reserved for MAC messages. F-port is comparable with TCP/UDP port number of TCP/IP.

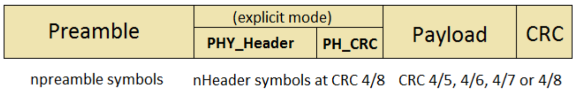

Fig. 7. LoRa Packet format.

Figure 7 shows the LoRa packet format where Physical Header (PHY_Header) which is added to the payload and encapsulates the applicable addressing information.

G. Adaptive Data Rate and Data Redundancy

The LoRa keeps data rate and transmitted power as a dynamic function of distance and SNR. The dynamic selection of SF compromises data rate for data redundancy. At a higher value of SF, packet time on-air will be higher. The redundancy of data is achieved using Forward Error Correction (FEC). FEC recover corrupted data bits due to interference or signal quality deterioration. A retransmission request is sent to the gateway if symbols cannot be retrieved. Hamming coding at Code Redundancy (CR) 4/5, 4/6, 4/7, 4/8 with synonym CR 1, 2, 3 and 4 selects required FEC.

H. Heterogeneous of LTE and LoRaWAN

Figure 8 shows the proposed heterogeneous LPWAN LTE network for charging infrastructure. Every EVSE is a Lora Class B device, exchanging information with EMU. EVSE connects to the LoRa gateway in the vicinity. If more than one gateway receives data, data specific to EMU are decoded from the address and excess received are swapped. EV user communicates with EMU via mobile LTE 5G networks. This eliminates any protocol that is required for the vehicle to interact with the EVCE. Location-based authorization can be made applicable for user authorization. Evaluation hardware for testing performance of the network for the range was implemented using SX1276 with ATMEGA32 for EVSE and SX1276 LoRa gateway. The test hardware could successfully transfer data at a range at an average of 3 Km in an urban environment, whereas up to 7 km in provincial.

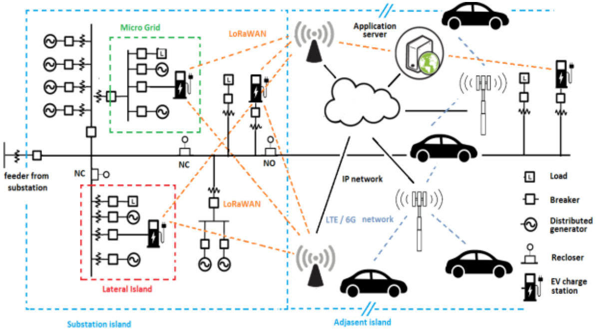

Fig. 8. Hetrogeneous LPWAN LTE/5G communication infrastructure.

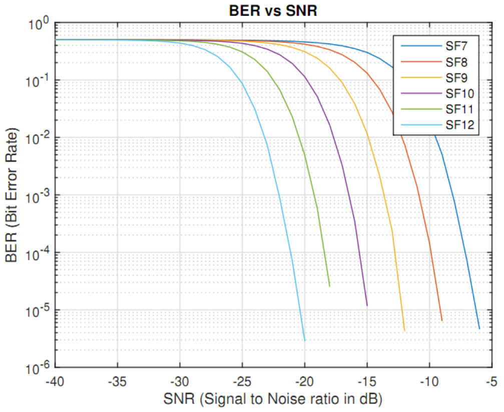

Fig. 9. SNR characteristics of LoRa WAN for various SF.

Figure 9 shows the simulation of LoRaWAN for Bit Error Performance for various SNR as a function of SF. Clear variation in SNR characteristics can be observed for a threshold level of 10^{-5}.

Table- II: Noise performance for different SF.

SF	SNR (db)
7	-6
8	-8
9	-12
10	-15
11	-18
12	-20

VI. RESULT AND DISCUSSION

The LoRaWAN technology is proposed as an apt protocol for establishing an LPWAN to support charging infrastructure. Offering a bit rate of 250 bps at SF 12 [17], the protocol is sufficient to meet the data requirement of the grid. The simulation shows better noise performance which extends to -20 dB with a BER performance of 10^{-5}. Though a theoretical range of 10 – 15 km [22] is proposed, the experimentation revealed coverage of 3 km in urban extent and 5km provincial with a transmission power of 14 dB at 31^o C using the standard gateway and SX1276 LoRa node. With around 100 packets transmitted the optimum performance was observed at SF 12. Figure 10 shows the SPI interface for SX1276.

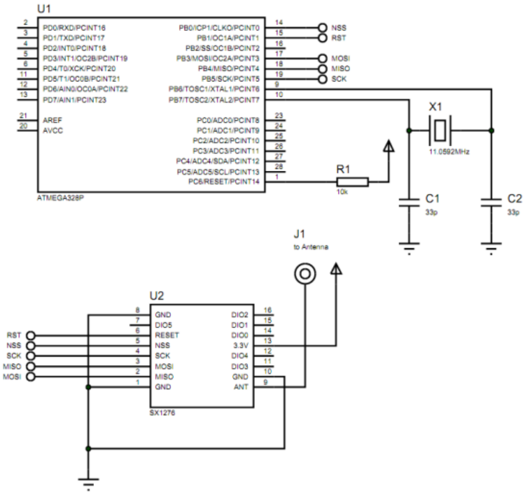

Fig. 10. Interfacing SX1276 with ATMEGA328 using SPI protocol.

The proposal put forward through the paper are summarized as

1) LPWAN technology blended with mobile data communication forming a heterogeneous network can provide ad-hoc network infrastructure for faster deployment of EV charge stations.
2) The new business models identified substantiate the need for ad-hoc data network to support EV charging facilities.
3) Many new technologies to support LPWAN are in the offing. Since most of these technologies offer interoperability. Hence redundancy in communication and range enhancement is not a matter of concern.
4) Through the adoption of the paradigm of IoT, as with any other "things" network, EV infrastructure is definitely benefited.

VII. CONCLUSION

Even though Smart Grid is a fully automated energy network backed by the flawless communication system, the communication infrastructure forming the backbone is not sufficient to meet the mobility requirement of EV charge infrastructure. Though the smart grid can meet an ever-growing demand for charging stations in urban reach, but the network has to scale beyond. Most of the standards and protocols set for smart grid usage are extended versions of Narrow Band Power Line Communication for communication within the grid. The paper discussed IEEE 1547 and 2030 standards for grid interaction as well as SAE J2931 and SAE J2836, about grid and EV charging infrastructure. The paper proposed a heterogeneous network of LPWAN and mobile data communication as a paradigm of the Internet of Things to ensure seamless usage of the grid. The necessity of the ad-hoc network to support EV charging infrastructure was discussed. LoRaWAN is suggested as the promising LPWAN technology to support EV charge infrastructure considering its range and noise resilience. There are many more technologies to support LPWAN are in the offing. The portability of technology in the context of the Internet of Things paradigm is supportive. In conclusion, it is important to adapt the paradigm of IoT to extend the stringent communication perspective of the grid to support the mobility of EV users and to extend the services beyond urban reach.

REFERENCES

1. S. Juyal, H. Sanjeevi, A. Saxena, S. Sharma, and A. Singh, "Zero Emission Vehicles (ZEVs): Towards A Policy Framework," NITI Aayog & World Energy Council, 2018, pp. 1–20.
2. C. Ramstein, G. Dominioni, and S. Ettehad, "State and Trends of Carbon Pricing 2019," International Bank for Reconstruction and Development / The World Bank, 2019, pp. 1–97.
3. J. Chynoweth, C. Chung, C. Qiu, P. Chu, and R. Gadh, "Smart Electric Vehicle Charging Infrastructure Overview," Smart Grid Energy Research Center, University of California, 2014, pp. 1–7.
4. X. Yu, and Y. Xue, "Smart Grids: A Cyber–Physical Systems Perspective," Proceedings of the IEEE vol. 104, no.5, 2016, pp. 1058–1070.
5. A. Zaballos, A. Vallejo, and J. M. Selga, "Heterogeneous Communication Architecture for the Smart Grid," IEEE Network, vol.25, no.5, 2011, pp. 30–37.
6. N. Saputro, and K. Akkaya, "A Survey of Routing Protocols for Smart Grid Communications," Elsevier Computer Networks, vol.56, no.11, 2012, pp. 2742–2771.
7. C. Madina, I. Zamora, and E. Zabala "Methodology for Assessing Electric Vehicle Charging Infrastructure Business Models," Elsevier Energy Policy, vol.89, 2016, pp.284–293.
8. F. Broek, E. Poll, and B. Vieira, "Securing the information infrastructure for EV charging," Springer Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, vol.154, 2015, pp.61–74.
9. B. Bhattarai, M. Lévesque, M. Maier, B. Bak-Jensen, and J. R. Pillai, "Optimizing Electric Vehicle Coordination Over a Heterogeneous Mesh Network in a Scaled-Down Smart Grid Test bed," IEEE Transactions on Smart Grid, vol. 6. No.12, 2015, pp. 784–794.
10. T. Basso, and R. DeBlasio, "IEEE Smart Grid Series of Standards IEEE 2030 (Interoperability) and IEEE 1547 (Interconnection) Status," NREL is a national laboratory of the U.S. Department of Energy, 2012, pp. 1–11.
11. S. Bayram, and I. Papapanagiotou, "A survey on Communication Technologies and Requirements for Internet of Electric Vehicles," Springer - EURASIP Journal on Wireless Communications and Networking, 2014, pp. 1–18.
12. M. C. Falvo, D. Sbordone, I. S. Bayram, and M. Devetsikiotis, "EV Charging Stations and Modes: International Standards," IEEE International Symposium on Power Electronics, Electrical Drives, Automation and Motion, vol. 1, 2014, pp. 1134–1139.
13. A. Usman, and S. H. Shami "Evolution of Communication Technologies for Smart Grid applications," Elsevier Renewable and Sustainable Energy Reviews vol.19, 2013, pp. 191–199.
14. A. Thomas,and N. V. Eldhose, "Scalability Concerns of Chirp Spread Spectrum for LPWAN Applications," International Journal of Ad hoc, Sensor & Ubiquitous Computing, vol.10, no.1, 2019, pp. 1–11.
15. B. Vejlgaard, M. Lauridsen, H. Nguyen, I. Z. Kovacs , P. Mogensen, and M. Sorensen, "Coverage and Capacity Analysis of Sigfox, LoRa, GPRS, and NB-IoT", IEEE 85th Vehicular Technology Conference (VTC Spring), 2017, pp. 1–5.
16. S. Lia , L. D. Xu, and S. Zhao,"5G Internet of Things: A Survey," Journal of Industrial Information Integration, Vol.10, 2018, pp. 1–9.
17. A. Thomas, and N. V. Eldhose, "LoRaWAN Scalability Analysis – Co Spreading Factor Interference," International Journal of Computer Networks, to be published.
18. Semtech (2015), "LoRa Modulation Basics", AN1200.22 Semtech corporation www.semtech.com, Revision 1, pp 1-26.
19. D. Croce, M. Gucciardo, S. Mangione, G. Santaromita, and I. Tinnirello "Impact of LoRa Imperfect Orthogonality :Analysis of Link-level Performance," IEEE Communications Letters, vol.22, no.4,2018, pp. 796–799.

20. G. Ferre, and E. P. Simon, “An introduction to Sigfox and LoRa PHY and MAC layers,” HAL https://hal.archives-ouvertes.fr/hal-01774080, 2018, pp. 1–7.
21. N. Sornin, and A. Yegin, “LoRaWAN 1.0.3 Specifications,” LoRa Alliance, Ver.1.0.3, 2018, pp 1-72.
22. A. Augustin, J. Yi, T. Clausen, and W. M. Townsley, “A Study of LoRa: Long Range & Low Power Networks for the Internet of Things,” vol. 16, no.9, MPDI Sensors 2016, pp. 1–18.

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