CARaM: COORDINATED ADAPTIVE REPLICA MANAGEMENT FOR CHARGING STATIONS

Thesis submitted in partial fulfillment of the requirements for the award of the degree of

Master of Engineering
in
Computer Science and Engineering

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CERTIFICATE

I hereby certify that the work which is being presented in the thesis entitled, "*CARaM: COORDINATED ADAPTIVE REPLICA MANAGEMENT FOR CHARGING STATION*", in partial fulfillment of the requirements for the award of degree of Master of Engineering in Computer Science and Engineering submitted in *Computer Science and Engineering Department* of Thapar Institute of Engineering and Technology, Patiala, is an authentic record of my own work carried out under the supervision of *Dr. Neeraj Kumar and Dr. Nidhi Kalra* and refers other researcher's work which are duly listed in the reference section.

The matter presented in the thesis has not been submitted for the award of any other degree of this or any other University.

Signature:

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This is to certify that the above statement made by the candidate is correct and true to the best of my knowledge.

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ABSTRACT

With an exponential increase in the penetration of electric vehicles in modern smart communities, the dependency on traditional fuel is decreasing from the last few years. However, to find an optimal and available place for charging of electric vehicles is still one of the challenging tasks. To address this issue, this paper proposes a technique to find the solution for coordinated charging using available infrastructures such as ZigBee network, remote sensors and street lights. The proposed solution is to use street lights as intelligent agents and connect them to a ZigBee network to the cloud database. Street lights are considered as base stations to send information regarding the status of a charging station (CS) to the database using the ZigBee network. An Algorithm Coordinated Adaptive Replica Management (CARaM) for CS is designed which is based on Iterative Deepening Depth First Search that uses the aforementioned information for the availability of CS in a geographical region. The nodes (CS) are stored in Binary Tree for fast retrieval of the information. The proposed solution has been evaluated and compared to other existing algorithms such as Breadth-first search and Depth-first search algorithms. The results obtained clearly demonstrate the superiority of the proposed solution with respect to the parameters such as overhead generated and less storage which are important variables.

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Chapter 1 Introduction

The phenomenon of electricity was observed very early. Around 600 BC, Thales described the results of static electricity & magnetism. During the 17th century, the characteristics of electrical energy were cultured. In the year 1799, a battery powered by electricity was made by an Italian physicist named Alessandro Volta. His name is further used to denote the unit of measurement for electromotive force & potential difference - the Volt (symbol: V). The 19th century witnessed research accelerate. In 1831, Michael Faraday observed that a magnetic field to be produced by an electric current thus the theory of practicing it in reverse also becomes possible: therefore by stirring a magnetic field, an electric current was formed. Succeeding these innovations, a Belgian electrical engineer named Zénobe Gramme designed the dynamo in the year 1868. After successful strides in the electrical sector, Thomas Edison invents the bulb eleven years later that brought a new wave to the progress of producing light in everyday life. In the very same year, the first hydroelectric power station came into operation in Switzerland.

Then came the question of transmitting the electricity, & the first power line placed down in 1883. & from 1889, a 14 km power line connecting the Jarrauds falls to the town of Bourganeuf in the Creuse (France) laid down. The very first high voltage power line was built & laid in 1891 between the two cities of Germany i.e. “Lauffen am Neckar” & “Frankfurt”. The debate surrounding the transmission of electricity by the alternating current or direct current has ended: with only a 4% loss, this new high-voltage alternating current line decided the imminent dawn of electric power diffusion. During the late 19th century, the manufacturing production of electric power became feasible & the pioneer methodological uses came into being: household lighting & phone.

The second industrial revolution had begun!

Electricity reaches into various areas of the social order such as railway transport, industry, path lighting afore it reaches homes. During the 1920s, the rapid growth of electric power made it feasible for electricity setups to deploy in industrial regions. Electricity has played a key role in the rapid industrialization & globalization of industrial societies for many years. Electricity is a key contributor to a nation’s economic development. It is the wheel that drives most aspects of everyday life in society. A nation is a compendium of activities & people whose progress is driven by the infrastructural components. Electricity is the source of fuel for so many sectors of an economy. We all live by electricity, our hospitals need electricity for the safe delivery of children & for surgery & other purposes. Our airports need electricity for them to work & ensure the safety of our aviation industry.

Every nation lives by the activities of her workforce & electricity are the number one amenity that is the lifeblood of many activities in the country. It is essential for our industries, they all need electricity for them to power their engines. The foreign missions in our countries & their businesses need electricity for them to have a comfortable life in the country. The welding & other artistry fields in our country need electricity to be able to work & all aspects of life in today's world are reflecting around electricity.

Electricity is so important to the economic development of every nation because it brings investment opportunities for the country. In a country with a fair share of electricity, investors come in because the cost of production in such a country is minimal compared to where there is no electricity. The electricity is cheaper compared to running on generators. Electricity helps to reduce the mortality rate in the country because the hospitals will be efficiently powered & such is a key factor in service delivery at hospitals.

In countries with better electricity, good production & preservation are higher. In such environments, agricultural productivity is high because, the electricity can help in powering irrigation, food preservation, & seed preservations. They enable the country to have fewer damages to agricultural products because they can be kept in storage facilities to avoid wasting them.

Electricity improves the standard of living of the people in the country. This is very important for the economic advancement of a country. If the people live in better conditions it has ripple effects on every aspect of the country. It reduces unwarranted expenditures for the government. It improves the security of the county & helps to create job opportunities for the entire country because the indirect sectors use the electricity to power their businesses.

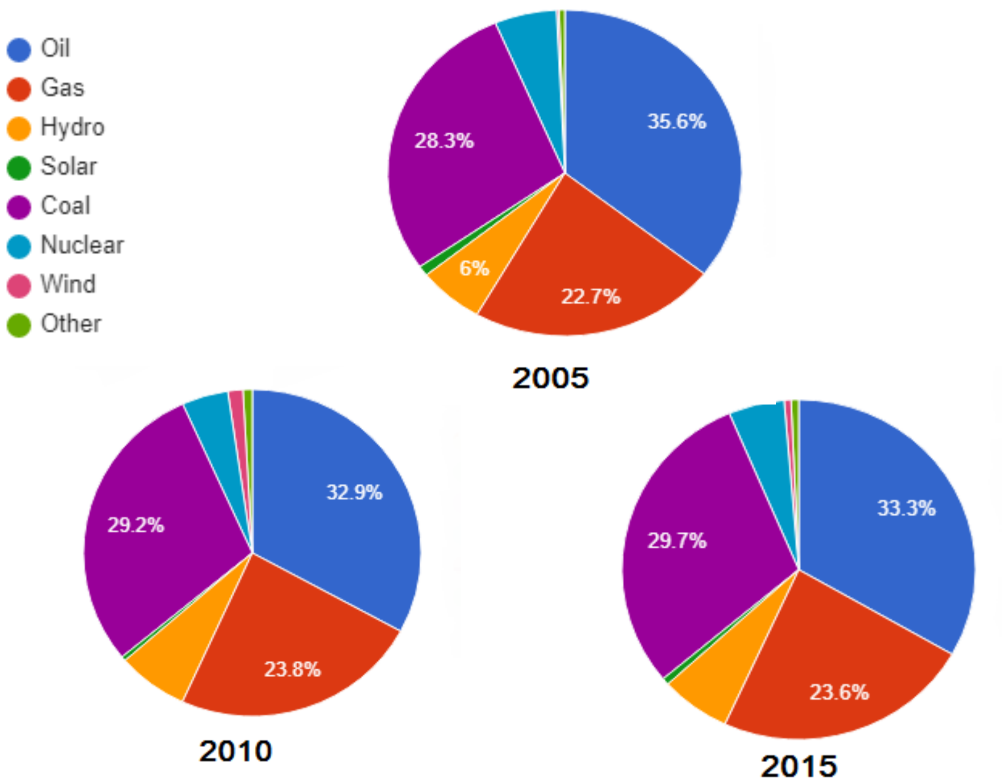

Fig.1.1. Comparison of energy consumption during the last 15 years.

The development comes when the keys drivers of the economy are unhindered by lack of infrastructural components of the country.

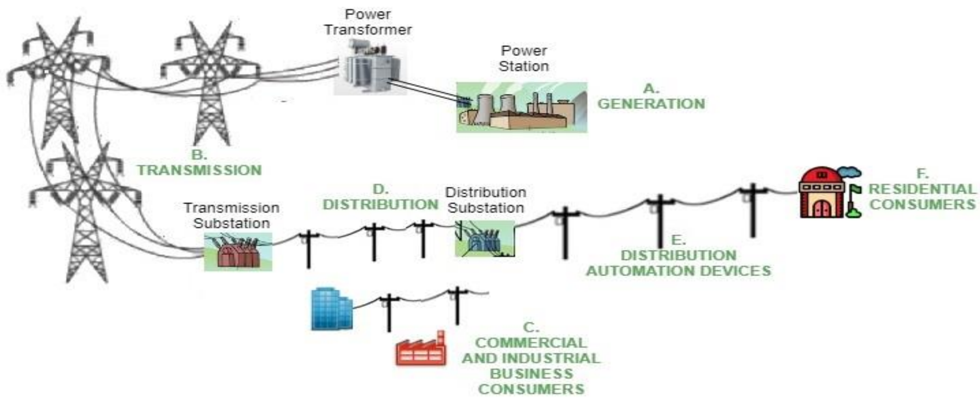

Fig. 1.2 Traditional Power Grid

Electricity has been customarily generated from conventional power grids but with the course of time, it has reached its saturation point. There are inevitable problems of conventional power grids constantly witnessing during the time like inefficiency & vulnerability. A maximum of 35% efficient electricity & a recent blackout on 2012 July 30th & 31st are such examples [1]. Also, there has been an increase in the number of smart devices including Electric Vehicles (EVs) that has intensified the load on the grid. As reported in the Techno-Economic Assessment of Deep Electrification of Passenger Vehicles in India, the added peak demand due to EV charging will grow up to 23 GW which is equal to 5.6% of the projected peak by 2030. Due to the increase in demand for eco-friendly vehicles with high efficiency, the number of EV will grow about from 3 million to 125 million by 2030 as reported by the International Energy Agency (IEA). It leads to the requirement of more efficient & reliable power generation & distribution systems. Based on technologies like IoT & Information & Communication Technology (ICT) for 2-way communication between utility & consumers, the Smart Grid comes into play to balance the supply-demand load on the grid. It characterizes with the augmented use of ICT in the generation, delivery, & consumption of electrical energy.

1.1 Introduction to Smart Grid

Our present power grid's concept was perceived 100 years ago during the times when the electricity requests were basic. Electricity production was confined around societies, small energy consumption was demanded by most homes for radio/transistor or a bulb. The power grid was intended for utilities to provide energy to customer's home & shape them once in a month, this one-way communication made it hard for the power grid to answer to the ever-growing electricity demands of today. The two-way communication was introduced when Smart Grid was conceived where information can be traded between its customer & utilities for energy demands. It's a developing web of automation, control, communication & computers, automation, & novel tools & skill operating collectively to create the grid more proficient, dependable, safe & greener. The Smart grid allows technologies to be cohesive like solar & wind energy creation & plugin EVs (electric vehicles) charging. An informed consumer helps the Smart Grid to replace the aged architecture of the recent power grid & utilities can converse well with them to help manage our electricity needs.

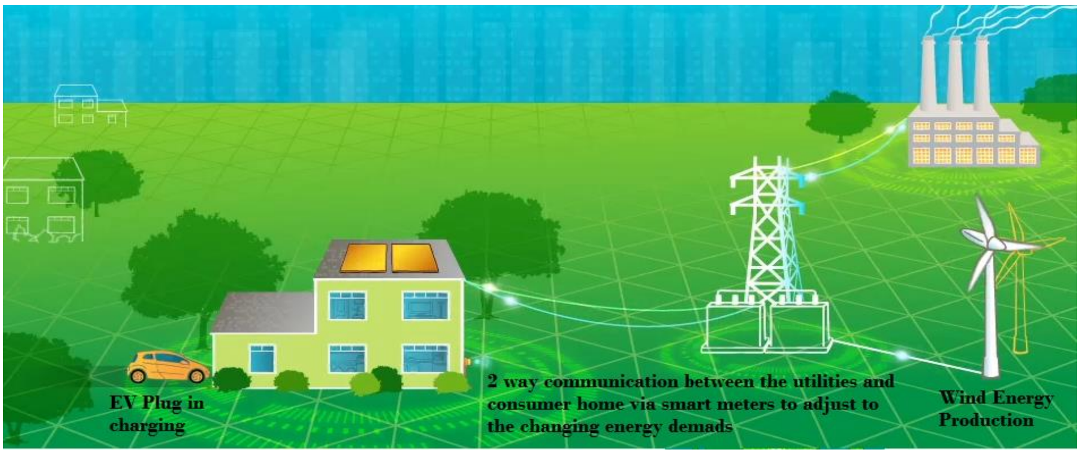

Fig. 1.3. An ideal scenario of Smart grid in action

1.1.1 How does Grid becomes 'Smart'

In brief, the cardinal technology that permits for mutual communication concerning the utilities & its consumers, & the sensors throughout the communication lines for better understanding of supply demand-load of electricity at a consumer's end builds the grid smart. Alike Internet, the Smart Grid is composed of controls, workstations, computerization, & novel tools & technologies working in cooperation, but in this end of deal, these expertise will cope with the power system to reciprocate to the rapidly altering energy needs. It will be a more flexible grid which will be able to integrate renewable energy & electric devices like electric vehicles into the network. This is part of a major transformation in the energy industry, the power is moving from the center to the edge of the grid. Previously passive consumers are becoming active participants in the network

The smart grid is still in its infant stage but soon we will be making informed verdicts about using the electric power in order to cope with our energy bill & aid the economy & environment.

1.1.2 Operations of Smart Grid

Smart Grid provides an unmatched prospect to shift the energy sphere of the current electricity sector into a new era of efficiency, accessibility, & dependability while contributing to our commercial & ecological health alongside. All through the transformation phase, it will be very important to facilitate technology developments, testing, improvement of norms & policies, consumer education & information distribution among projects to guarantee that the benefits we foresee from the Smart Grid turn into realism. The profits related to Smart power Grid involves:

1. Proficient communication of electric power more than ever.
2. Faster re-establishment of electricity after outage or power disturbances.
3. Lesser power pricing for consumers by minimizing the processes

& organization charges for services.

4. Lower electricity rates as peak demands will be minimized
5. Smart grid encourages the increased cooperation of far-reaching renewable verve setups thus shares the burden of energy from nonrenewable energy sources.
6. Better incorporation between the owner-customer energy generation systems, involving the renewable power setups.
7. Helps in improving the security

As of today, a power disturbance like a power outage can have a ripple consequence—a succession of disappointments affecting the security, infrastructures, & banking. The known danger in the winters is that the customers can possibly be left without heat which produces severe consequences. A Smart power grid will improve reliability to the electricity setup & pull off a pre-ready system to discourse tragedies such as huge solar blazes, miscreant assaults, earthquakes, & severe storms. Because of Smart grid's two-way interactive ability, it will sanction reflex redirecting whenever device fails or blackout occur. This whole setup will reduces outages & reduce the impact whenever they do occur. Whenever a power blackout happens, Smart Grid establishment identifies & segregates the blackout, prevent them afore the blackout on a bigger margin. The novel tools like IoT aids in ensuring that the electricity recovery recommences as fast as possible & tactically after a disaster—redirects power to crisis utilities. The Smart power grid involves toting software & sensors to the established power grid that ensures utilities to help understand & react to changes quickly as per the individual's information gathering. Let's say a tree falls on a power line & 1000 homes lose power, the utility employees physically reroute electricity which demands a lot of time. With Smart grid sensors & software, it would detect & immediately reroute the power, control the outage to lesser number of homes, & manage the fluctuating cost of electricity that alters through the day- it might be high during peak active hours & low during the night. With the aid of Smart meters (a component of the Smart grid facility) at your homes, you could set to run appliances requiring high energy like dishwasher or washing machine to run when power is cheap, thus providing more energy control on your electricity bill & helps prevent blackouts during high consumption hours. The smart grid also provides a novel means to practice energy from RES. Power generation can now be further dispersed through various sources so the grid is more steady & proficient. It’s the capability of communicating & managing electric power that ensures the grid to be smarter & aids in avoiding burning more fossil fuels later.

Previously passive consumers are now becoming a vital cog in the Smart grid facility as the customer may even become producers of power, feeding surplus energy back into the grid. In layman terms, Smart grid will receive major advantage from customer-possessed electric producers to generate energy when it’s inaccessible for the surplus demands from the utilities. By combining the "distributed generation" resources i.e. renewable energy sources & consumer-owned power generators, a community could keep running its grocery store, phone system, police department & health center operating during the emergencies. Furthermore, the Smart Grid paves the way to discourse an age-old electric power setup that surely requires to be progressed or traded. It’s a mean to acknowledge power efficiency & increase alertness among the customers regarding the relation & understanding between energy usage & the surrounding. & it’s a mean to fetch augmented national safety to our energy setups—withdrawing on huge sums of home-produced power which is more resilient to natural crisis & assaults.

1.1.3 Control Comes to Customer

The Smart Grid is about providing the information & tools so that the customers can make decisions about their daily energy consumption. As of today almost every being is capable of managing & organizing activities like managing personal banking affairs i.e. checking bank statements, managing accounts, etc., imagine managing the electricity in a similar fashion. The smart grid enables customer participation at an unprecedented level. For instance, a customer now does not have to be a stand-in for its periodic electricity bill to understand its past month electricity consumption. A Smart Grid gives real-time & a clear picture of it. "Smart meters," & other facilities enables the consumer to monitor their electricity consumption at real time & also its price. Pooled with live tracking of cost, this conundrum enables the consumer spend less on bills by avoiding using the electricity when the pricing is high during peak hours. Although the usual advantages of a Smart power grid are every so often lies in the region of national safety, sustainable energy, & economics, but the Smart power Grid also possess the promising tools to aid the consumer in saving money by providing help to organize their electric use & even allow them to generate power for their own via renewable means like solar panels thus save even more money.

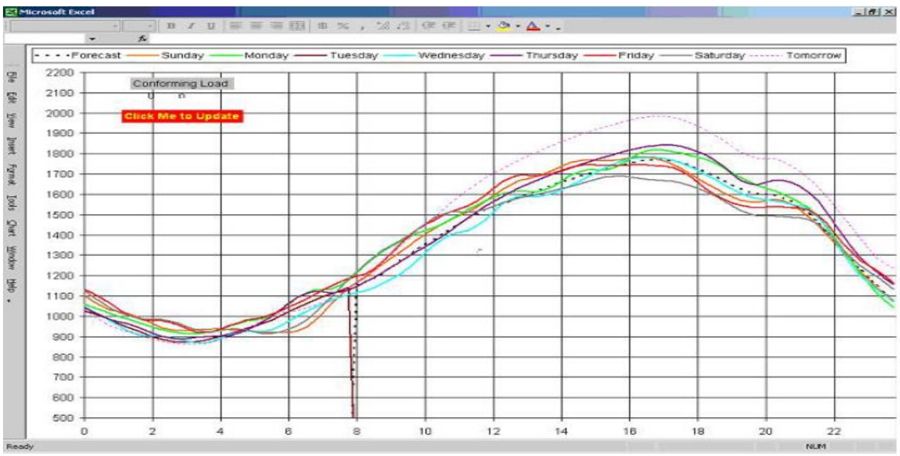

Fig.1.4 Daily Load Profile

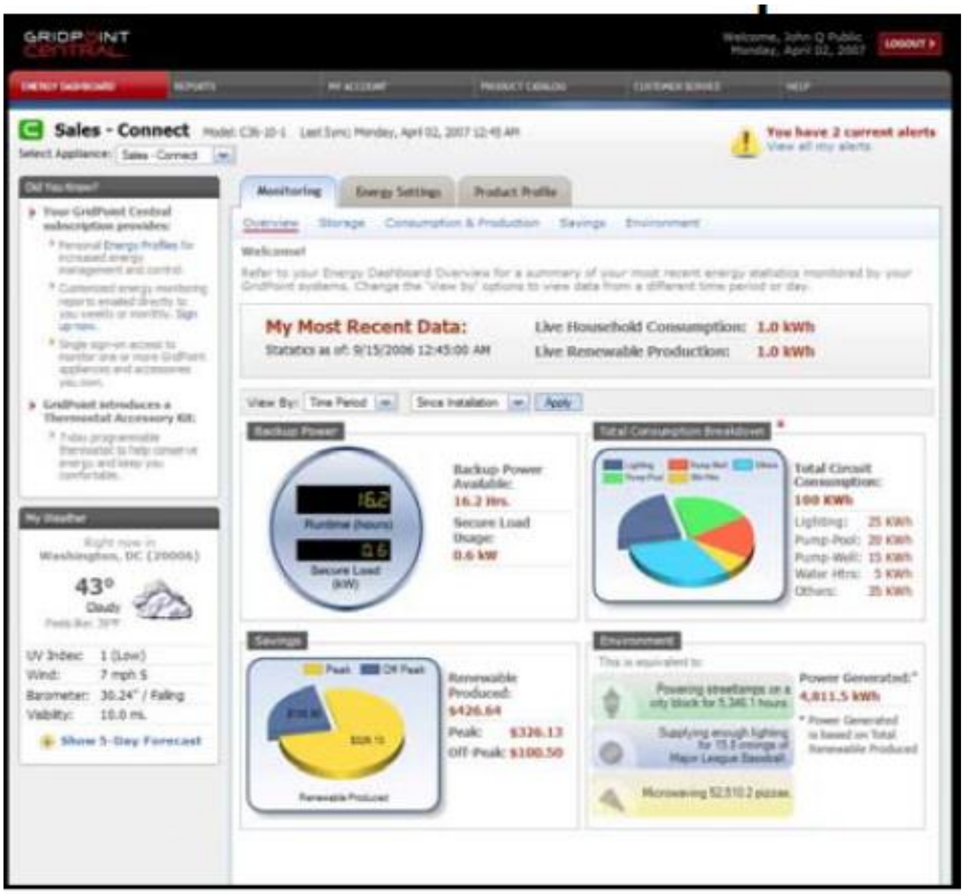

Fig.1.5 Snapshot of customer interface to monitor electric usage and pricing

1.2 Smart Grid Framework

The Aggregated intricacy of traditional electric power grids, the ever-rising demand for electric power & necessity for better network proficiency, safety, & dependability along with the concerns for the ecological & power sustainability linger on to highpoint the requirement for a giant jump in binding information technologies & communication. This drive towards a smarter power setups is now mainly mentioned as "smart grid". A structure for unified incorporation of information technology & two-way communication has simplified the convergence of highly needed protocols & standards & protocols that helps in the implementation of necessary analytical capabilities. An ideal mix of sustainable sources, request response, & stowage leads to blandish overall request that gradually accentuates reliability issues later. An electric grid fundamentally functions as following. Customarily, power is produced in a principal power plant with the help of electromechanical producers. The electric power plants are huge & thus located at remote areas. The utility i.e. electricity when to be transmitted is then amplified in the transmission system.in order to transmit the power over long distances to remote substations. On reaching the remote subsystems, the power is de-amplify from the previous amplified transmission level to a level needed for distribution. After the electricity power leaves the remote subsystem, it reaches into the dissemination facility. Lastly, after reaching at the local service locality, the electricity is de-amplified for a second time from the dissemination charge to a level of required charge(s). This procedure underlines the general concept of distribution, transmission, bulk generation, customers, market, operations, & a service provider [2] which is also shown in fig 1.3. These domains & subdomains are interconnected with each other.

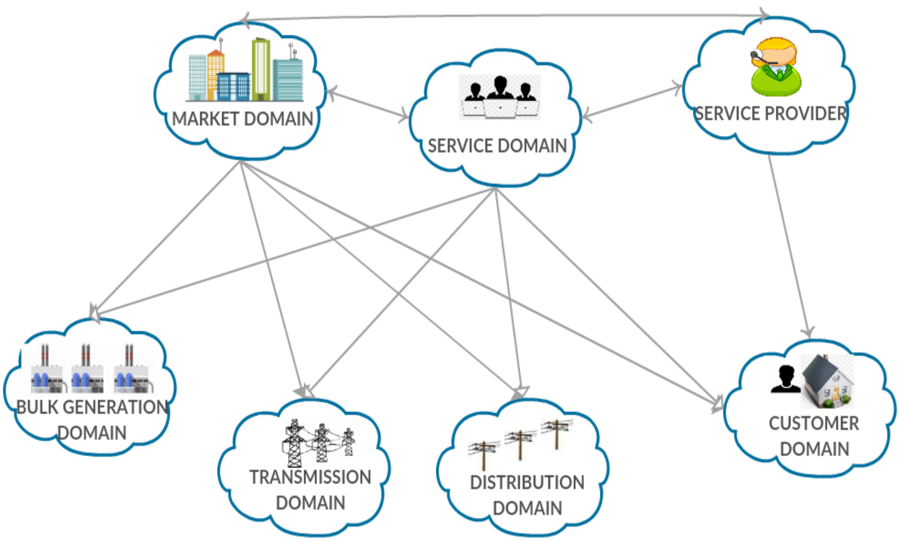

Fig. 1.6 Components of Smart Grid Framework

1.2.1 Bulk Generation

The players in this setup are accountable for the majority of production of the utility i.e. electricity & the corresponding recording procedures, control, measurement, & protection. Thus the information management fragment in this setup should

1. Log important vital operational & excellence of facility parameters like paucity (mainly in solar & wind) & letdowns.

2. Make a perfect use of data gathered by the market sub-system to provide 'availability of electricity' data to the market & simultaneously schedule generation.

3. Create a log inclosing the history of maintenance & device operations & scrutinize the performance & lifespan of devices.

4. Manage the strength & flow of power because without it the system will collapse. The generated power should be equal to the power demanded

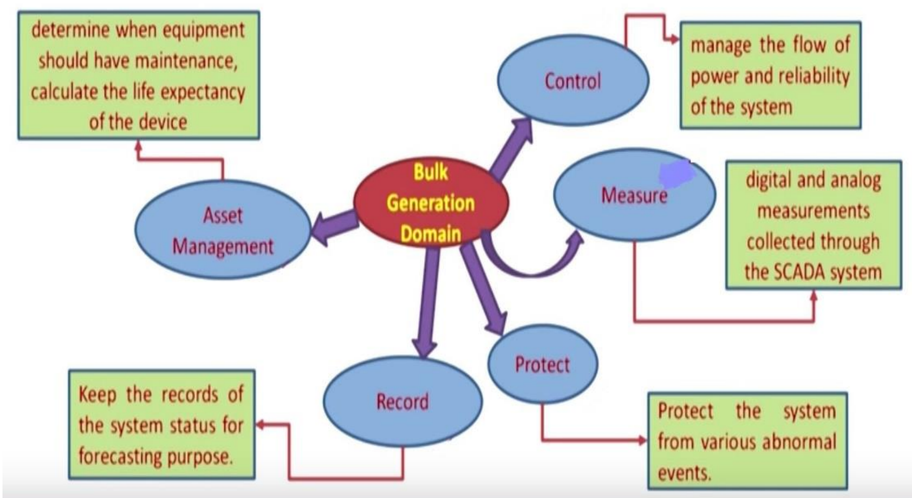

Fig. 1.7 Bulk Generation Domain

1.2.2 Transmission

The communication facility is the carter of the greater part of electric power over faraway. The info management fragment provides information exchange, nursing, & regulate data for processes as well as control of communication remote subsystems & ground level tools. This data is gathered by fairly established monitoring & measurement devices, such as phasor measurement units & sensors [3]. However, to organize the processes in communication facility includes improving asset utilization, energy flows & refining dependability; the information gathered should be used wisely.

1.2.3 Distribution

The distribution structure is the junction of the customer sub-domain & the transmission facility. The Smart Grid distribution structure communicates in real time with the operation sub-domain to organize the energy flows accompanied by a lively market subsystem thus quickly fine-tune localized generation & consumption. The information management part should provide nursing & regulation data, comprising of distribution system reliability & load management.

1.2.4 Customers

The consumer is the biggest shareholder of the whole facility for which the entire power grid system came into existence in the first place. Smart grid has enabled the customers to organize the electric power production, storage, & usage. The understanding of several progressive users sorts, such as control of distributed generation, in-home showcase of consumer usage, remote control, control on new electric devices (e.g. electric vehicles) & automatic reading of meters can be achieved & supported by information systems & two-way communication.

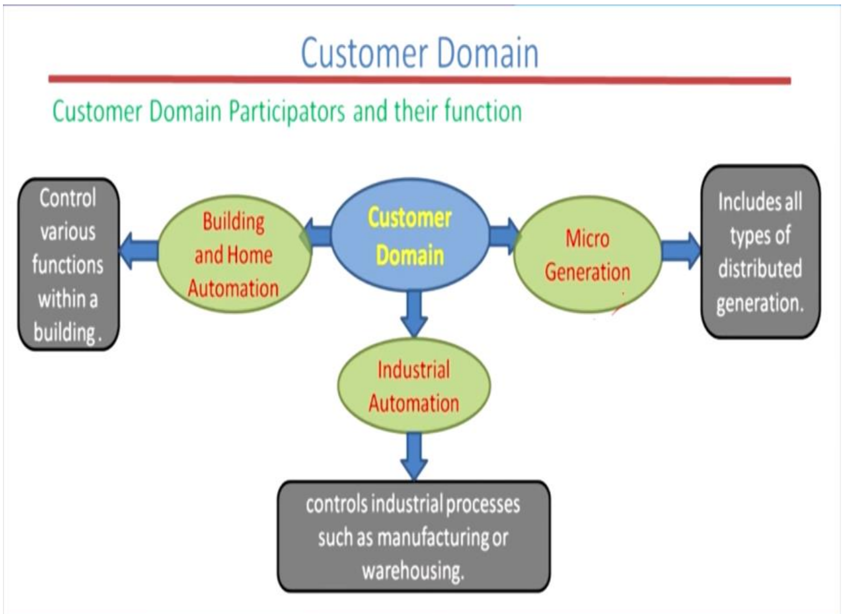

Fig. 1.8 Customer Domain

Customer consumes electricity & is categorized in the following 3 types on the basis of their energy usage requirements:

1. $0 \leq 20$ kW home appliances
2. 20-200 kW for commercial/building
3. $\geq$200 kW industrial power sector

For every type of customer, a smart meter & a special gateway are deployed throughout the infrastructure, while to enable a 2-way communication, Energy Services Interface (ESI) is used which provides secure end interface to the utility for the customer interactions. Customer interaction is made possible through AMI (Advanced Metering Infrastructure) as they are connected with each other with the help of internet. The main part of the customer domain is building home automation, industrial automation, & micro power generation.

1.2.5 Markets

The market is the source & destination where assets for the grid are being sold & bought. The information management fragment of this specific sub-domain is to provide data support for the evaluation & optimization of the energy trading between bulk generators, operators, customers, & utilities & for the balance of demand-supply load & pricing.

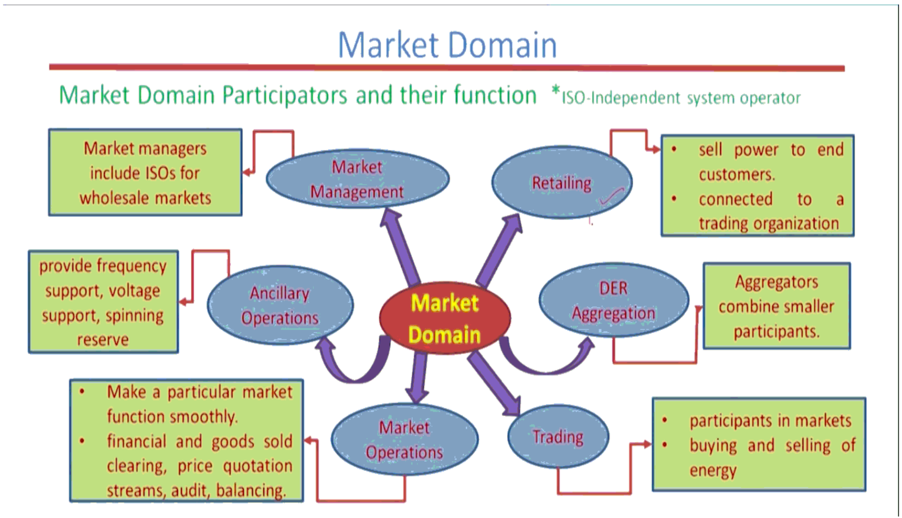

Fig. 1.9 Market Domain

1.2.6 Service Providers

The participators in this sub-domain are deployed to aid the business practice of other actors present in the grid framework. Electric service providers, pre-existing third parties or newly involved participants allured by the business models are some actors while providing services to the end user. These business processes vary from customary services like bill payments & consumer account organization to better consumer facilities like organization of power consumption & homegrown power production [3]. All of the aforementioned processes need participation from the info controlling setup, which

1. Organized consumer data;

2. Assured load control by the customer at its end to utilize the energy consumption data & pricing to save money;

3. Presents an operational interface amongst the consumer & the sooqs for the data interchange; &

4. Be responsible for providing the data provision required for the evolving facilities.

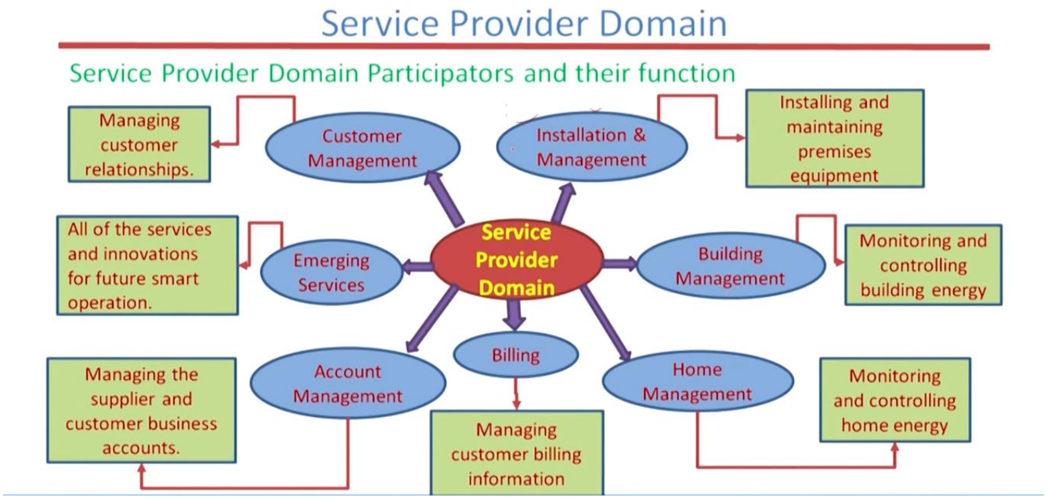

Fig.1.10 Service Provider Domain

1.2.7 Operations

The participators of sub-domain accounts for the process of the electric grid setup & the administration for transmission & distribution of power. For achieving reliability & a safe power grid, the info organization fragment for this sub-domain would aid editing, combination, authentication, approximation, & assessment of the operating, nursing, dimension, & metering info collected from the electric network. It provides flawless functioning of the critical power infrastructure. The main goal is to control, operate, maintain, & monitor the smart grid in a very secure, dependable & reliable manner. Operating network has to very smoothly without any hindrance & problem thus no power cuts at any time should be expected also the quality of power is maintained at all cost.

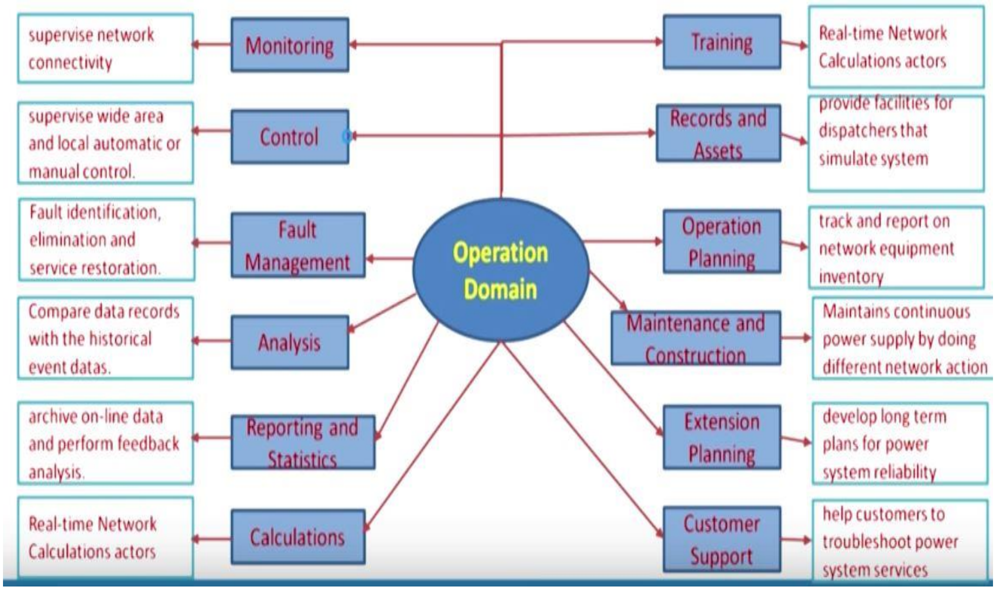

Fig.1.11 Operation Domain

1.3 Challenges in a Smart Grid Framework

Smart Grid's SCADA framework is an automation control system to sense system overloads & anticipates the supply-demand gap to minimize the potential outage. In spite of its many advantages, it still poses serious challenges, The strategic challenges in a Smart Grid Framework are exposure to radio frequency (RF) radiation[3][4], strengthening the grid, Communications, Integrating intermittent generation, capturing the benefits of DG & storage & preparing the framework for electric vehicles [5].

- **Exposure to RF radiation**: It seems to affect the most at the end level i.e. the client of Smart Grids. The motive is due to the presence of electric appliances that transfers wireless data continuously almost every second of the day & that too with high power bursts which are above than the placed safety standards i.e. frequencies ranges between 917 MHz & 3.65 of the electromagnetic spectrum. With the presence of 'Smart metering' mechanism at the client's end, every other single electrical appliance is equivalent to a cell phone transmitting RF signals. To avoid such situations we need to avoid interference of frequencies of multiple appliances as mentioned above a home environment nowadays comprises of multiple wireless technologies like Wi-Fi & ZigBee that generally operates in the ISM 2.4-GHz frequency band. On top of it, the home appliances also operate in the same Wi-Fi/ZigBee based crowded ISM band [6].

- **Strengthening the grid**: With the increasing number of energy resources – renewable & non-renewable, there is a rising need in the energy sector to ensure that there is an adequate transmission capability in order to interconnect multiple energy resources spread across the region, especially renewable resources. In order to facilitate Smart Grid deployment, established norms & finest performs are needed to be willingly smeared without any compromises over the norms & protocols of the standards. The main issue is the scarcity of the awareness of such standards while planning Smart power Grid setups at the basic standard & a dearth of the finest performs & control norms while deployment.

- **Communications**: With the introduction of smart technologies like ICT, IOT & other communication supported technologies in the smart grid architecture, there has been another deterrent challenge after the inclusion of aforementioned that is to deal with Smart metering communications, interoperability & overlay networks many more[5].

- **Capturing the benefits of Distributed Generation and storage**: Usually, the power grids (in our case Smart Grids) are remotely located at far distant places & thus capturing the benefits of Distributed Generation & storage still poses a challenge. It can be endured with the support from adjacent energy resources to maintain synchronization & heftiness in contradiction of the sporadic outages. The usual methods consist of the usage of petroleum product-driven producers, supercapacitors, compacted wind setups, flywheels, & batteries. Their influence on environment is vital since the usage of RESs (Renewable Energy Sources). It is sternly linked to delivering more sustainable energy processing. The challenge that can be confronted will be unusual ramp rates & Intermittency (the irregular alternation of phases) limiting the renewable sources power output.

- **Preparing the framework for electric vehicles**: The emergence of electric vehicles has not only increased the option for the modes of transport & made a big stride forward for a greener & sustainable environment but also in the utilization of rechargeable batteries which requires grid support, which in broad terms referred to as V2G i.e. Vehicle to Grid. In V2G concept, when EVs are joined to the electric grid, the power is served by two means: 1) EVs are linked to the residential grids in homes, 2) EVs are amassed to the communication systems in combinations. Another way is that a vendor will amass EVs into sections to vend in huge power, which led to the rise of independent & regional Charging Station (CS) networks. However, it is still in an early stage & a structure is required to its implementation which has been a challenge to its adoption [6].

Chapter 2 Literature Survey

2.1 Electric Vehicles for Sustainability

The transport sector is accountable & has been the largest contributor to air pollution in general as well as being the biggest cradle for the emission of greenhouse gas (GHG). A 2012 report based on data gathered by WHO estimates 30-33% of all the deaths i.e. 3.7 million premature deaths are associated with out-of-doors air pollution. Largely, increased air pollution levels augment the threat for respiratory & cardiovascular diseases, adverse birth outcomes & cancer, & also are attributed with increased death tolls.

Deaths & illness related to air pollution are related mostly to contacts to small particulate matter (PM) range from 10 to 2.5 microns in diameter (PM10 & PM2.5). These small particulates matter circumvents the body's fortifications against dust, probing deep into the respiratory channels of the body. These particulates usually consist of a blend of substances, such as carcinogens including benzene derivatives, Sulphur's carbon-heavy metals, Sulphur's, carbon compounds, &.

The transport sector is a major & increasing contributor to air pollution. Road transport is likely to be accountable for up to 30% of emissions of particulate matter (PM) in European cities & it increases to 50% in the Organization for Economic Cooperation (OECD) countries. Although, the total involvement of road transport to air pollution varies from 12%-70% of the total pollution. Due to the use of inefficient & old diesel vehicles & a scarce public & active transport network, Underdeveloped & developing countries suffer the most from transport-generated pollution, particularly in Asia, Africa, & the Middle East.

Transport delivers access to services, jobs, recreational activities, & education. Many weak & vulnerable groups, like low-income groups, children, women, elders, & disabled persons have low or negligible access to a personal vehicle; they depend on public transport, walking or cycling. Air pollution also inclines to poor vicinities excessively, since lower value homes may be positioned in close range to heavily trafficked areas.

As a result, refined & improving public & non-motorized transport can recover health parity in two ways: unswervingly reducing the air pollution, & harmful respiratory & Cardiovascular risks in neighborhoods, & secondly, by improving accessibility & mobility, we tend to put fair share for the vulnerable & weak groups of society.

Another transport-linked air pollutant that troubles health take account of ground-level ozone (O3) - a blend of urban air pollutants & an important cause in respiratory ailments like asthma. Few of the forerunners of O3 contains methane (a strong greenhouse gas), nitrogen oxides (NOx) & carbon monoxide (CO), which stances a certain risk for vehicle owners & passersby in closed spaces (e.g. garages). Ground-level ozone also notoriously damages the ecosystem edifice & functions, in turn distressing the agricultural efficiency & intimidating food security.

Thus arises the need to find an alternative to fuel-driven vehicles which in turn reduces the pollution & contributes towards a sustainable environment. Electricity nowadays represents a large proportion of the energy consumed worldwide. Electricity can be produced via various sources, the most recent is a generator in which mechanical energy is converted to electrical energy. The mechanical energy is derived from a thermal source, which itself is a derivative of other energy sources. Electric power can also be generated from solar energy, wind energy, hydro energy, & chemical fusions like in batteries. The desire to produce electric power while keeping the carbon emissions at the minimum & encouraging renewable energies is the call of the hour.

Since the 1990s electricity generation & study on climate change due to greenhouse effect have become a central concern for the society. Countries energy freedom & admiration for nature are now topics of open debate. The **Kyoto Protocol** for climate change was signed in the year 1997 to strengthen the ecological facets of the world's energy regulations & in specific in Europe's energy norms. Thus moving forward in order to maintain & look forward towards a sustainable environment, the transport sector needs to make huge changes as they are 20-70% responsible for the air pollution leading to the greenhouse effect. One way is to produce very efficient fuel engines & another way around is to introduce the Electric vehicles into the market & it seems the Transport sector has chosen the latter.

2.2 Introduction of Electric Vehicles

As per the report of VP SOLAR on "Statistics of sales of electric cars worldwide" [5] shown in Fig.1.12

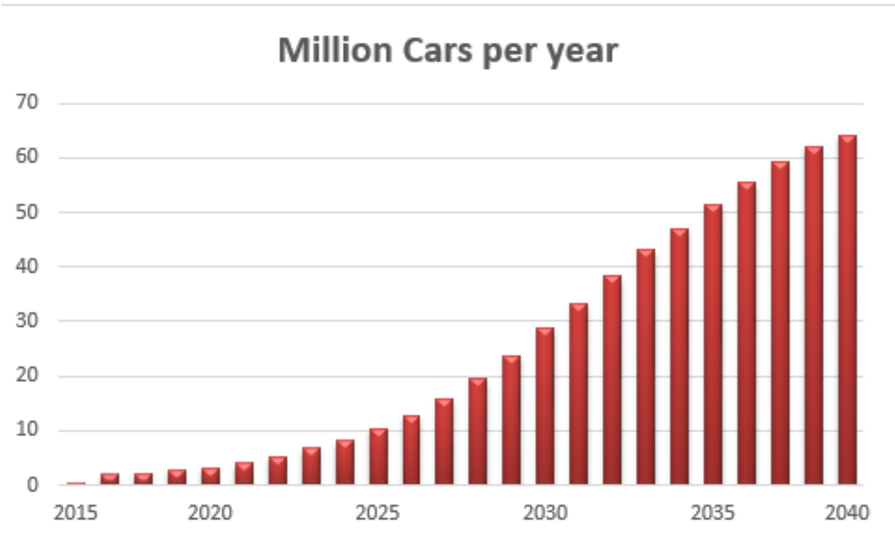

Fig. 2.1. Annual sales of electric cars in the world

The exponential increase of EVs faces the problem of preparing the framework to support the same is one of the widely discussed challenges. The emergence of electric vehicles has not only increased the option for the modes of transport but also in the utilization of rechargeable batteries which require grid support, which in broad terms referred to as Vehicle-to-Grid (V2G). In V2G concept, when electric vehicles are connected to the power grid, the power is fed by two modes: one is that vehicles are joined to the residential grids in homes, the other is that vehicles are amassed to the transmission systems in aggregations. Another way is that a third party could aggregate EVs into blocks to sell in bulk power, which led to the rise of independent & regional CS networks. However, it is still in an early stage & a structure is required to its implementation which has been a challenge to its adoption [6].

Consequently, the CS network is laid down in order to provide a scalable solution to the increasing number of EVs. But the problem of “in service & available” CS still persists. To address this problem the requesting EV need to be aware of the network of available CS around it. It can be done if either the logs of the CS or its replica can be stored in potential storage. Lookups in storages will let the EV know about the available CS in the network, which leads to the challenge of replica management. A Replication Manager (RM), is required that will have an up-to-date global view of the system. It will be responsible for decision-making about when to acquire replicas & when to release replicas based on perceived performance & replica utilization. These certain features require an extra infrastructure that increases the load on the framework, thus have been avoided ever since.

Although, works based on the former problem also exist in the literature. For Example, the problem of CS placement with the charging of EVs & integration into the power system is explained by **Luo et al.** in [7] which discusses the relationship between the power grid system & a large-scale electric vehicle (EV) charging system. The author adheres to the three vital issues related to the EV charging & its further amalgamation into the power system which are

- Placement design for Charging stations over the region,
- Energy management strategy & pricing standards, &
- Distribution network policies & electricity tradeoff market to ease the integration of renewable energy source (RES) & Electric Vehicle into the power grid system.

To adhere the placement problem of charging station, the author suggests a multi-stage customer conduct based placement tactic with incremental EV permeation rates & design the EV charging sector as an oligopoly where the whole market is subjected by a few charging service providers (oligopolists). The optimum placement procedure for every service provider is acquired by solving a Bayesian game.

For energy management & pricing strategy of Electric vehicles charging stations, the author suggests norms & regulations for charging service providers to control charging price & organize electricity reserve to poise the competing purposes of improving customer satisfaction, reducing the load over the power grid system, & profitability. Two algorithms --- greedy algorithm (benchmark algorithm) & stochastic dynamic programming (SDP) algorithm are useful to evaluate the pricing & electricity attaining strategy.

The author **Luo et al.** design an unusual electricity tradeoff market & distribution network, which aids unified renewable energy resources integration, vehicle to grid (V2G), grid to a vehicle (G2V), distributed generation (DG), vehicle to vehicle (V2V), & storage. A partaking economy model is smeared to the electricity industry to stimulate a variety of entities to swap & monetize their unused electricity. A fitness-score (FS)-based algorithm is developed taking into the consideration of consumer surplus, economic dispatch & electric network congestion to balance the supply-demand load at the power grid & at the charging service providers.

The complexities in charging are proposed by **de Weerdt et al.** in [8] that discuss the problem of optimal scheduling of the charging demand of electric vehicles. In the smart grid, the motive is to use tractability in demand, both to poise supply & demand as well as to solve possible congestion. A first noticeable instance of such flexible request is the charging of electric vehicles, which do not essentially want to be charged as soon as they are plugged in. The issue of ideally scheduling the charging request of electric vehicles within the restrictions of the electricity arrangement is called the charge scheduling issue. The designs of the charging demand, horizon & charging speed evaluate the computational complexity of the charge scheduling issue. For about 20 types, the author uses a dynamic programming approach to solve the charging scheduling problem which is either weakly NP-hard or P- presenting a possibly substantial hurdle to their use in everyday situations.

2.3 Optimal Charging methods

The problem of finding parking is addressed by **Joy et al.** in [9] that investigate the smart charging & parking of plug-in hybrid electric vehicles (PHEVs) in microgrids in grid-connected mode. The aim to allocate CS in industrial microgrids (IMG) with the objective of minimizing system costs in order to ensure a profit to the owner is subjected by **Chung et al. in [10].** The author examines the pricing scheduling issue of electric vehicles (EVs) at the power grid system. This problem consists of a set of charging stations organized by a central aggregator. The operator who look after the charging station is usually the main stakeholder of the charging stations, who is encouraged to lower the cost gained by the charging stations, whereas the vehicle owners who are the other major stakeholders are mainly fascinated in user comfort, as they want their electric vehicles to get fully charged within no time. Thus an optimization function is designed while considering both the aforementioned objectives to mutually optimize the factors that match up to these stakeholders desires. A Pareto-optimum solution is to provide an online scheduling algorithm which will be centralized for monitoring purposes in order to avoid tweaking the charging prices as per their needs. Furthermore, an inventive low-complexity algorithm is recommended to minimize both the computation complexity & transmission data rate in the grid system. The algorithms are determined by multiple simulations, & results describe that the time spent on charging an EV in the proposed manner is 30% fewer than that of the methods mentioned in the literature. The data communicated by the strewn algorithm is 33.25% lesser than that of the algorithm which is centralized. Whereas the performance varies between the distributed & centralized algorithms are only 2%, but the computation time displays a noteworthy reduction. Therefore, a low-complexity distributed system was projected to get the performance level similar to that of the centralized system, which also considerably reduces the number of communicated messages.

The charging of multiple EVs at once is discussed by **O'Connell et al.** in [11] by the concept of dock-Chain charging. The author discourses Charge Point Anxiety adjoining EVs which is a problem averting the bulk acceptance of EVs – a better & eco-friendly means of travelling. The author discusses the scheme & application of a charge point connector known as dock-Chain which supports in remove the Charge Point Anxiety problem. The main characteristic of the dock-Chain is that it enables several electric vehicles to attach altogether to one charge point as the connector will join ad jointly, causing in extra charging prospects. The author illustrates the process of the grid of connectors, the H/W mechanisms & charging regulations for the connector. A scattered system that can identify the span of the sequence of EVs in a dock- Chain system is also offered.

The dock-Chain connector allows multiple admittance to a lone charge point. It allows the connectors to join organized in a 'surging' fashion to build a setup that allows various EVs to get charged concurrently. The 'surging' characteristic is a key novelty for this connector. It relieves the grid from the feeling of Charge Point Anxiety as it can increase the range of charge point accessibility. In particular, it avoids a lone electric vehicle obstructing the charge point. Also if the first EV vendor who reaches at a charge point practices this connector it enables another EV vendor to reach later & yet can charge their vehicle.

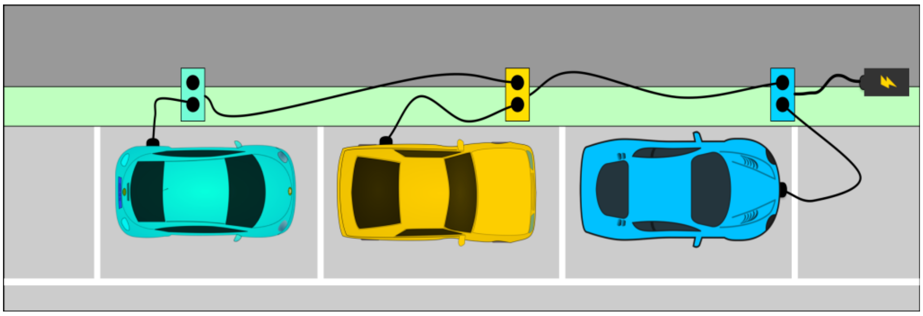

Fig.2.2 Three vehicles connected to a single charge point and charging simultaneously using three dock-Chain adapters

Liu et al. [12] projected a vehicle-to-grid regulating arrangement by means of EVs to underwrite in basic incidence control of the setup in view of the "charging requests" of Electric Vehicles. Vehicle-to-grid (V2G) regulation has the perspective to deliver incidence instruction facility for network power system process from electric vehicles (EVs). A distributed V2G control (DVC) method is projected for EVs to underwrite to important frequency control seeing charging requests from EV customers. When an EV consumer wants to uphold the remaining state of charge (SOC) of the battery, a V2G regulator method, called battery SOC holder (BSH), is executed to uphold the battery energy about the residual SOC along with adjustable frequency control. If the remaining battery energy is not sufficient for the next journey, the customer needs to recharge the EV to a higher SOC status. Then, a smart charging technique, termed as charging with frequency regulation (CFR), is industrialized to provide frequency regulation & scheduled charging both simultaneously. Recreations on a two-area interrelated power system with renewable resource incorporation have exposed the efficiency of the projected technique.

Masoum et al. [13] castoff EVs for shaving the top in housing load request that betters the voltage accounts & projects a smart response supervision method. Novel smart load management (SLM) methodology for synchronization of various plug-in electric vehicle (PEV) mounts in delivery feeders is anticipated. Plug-in electric vehicle are increasing in fame as a less carbon emitting & proficient means to travel contrary to fuel-driven automobiles. Plug-in electric vehicle chargers resembles large & capricious tons, which can adversely influence the throughput of dispersal power grids. Services are afraid about the voltage deviations, stresses, power loss & potential overloads that may happen in distributed power grid systems from native PEV charging commotion as well as from freshly developing charging stations. Consequently, the author proposes a novel SLM control tactic for synchronizing PEV charging established on peak demand shaving, refining voltage profile & reducing power losses. Moreover, the advanced SLM methodology takes into thought the PEV vendor preferred charging time precincts based on a primacy selection scheme. The influence of PEV charging points & typical loading patterns are also taken into account. Simulation outputs are presented to validate the significant performance progress presented by SLM for a 1200 node test architecture comprising of multiple low-voltage residential topologies populated with PEVs.

Deilami et al. [14] put forth a real-time synchronized scheme for charging of EVs & PHEVs to lower the power losses in the smart grid. The author projected a new load management resolution for synchronizing the charging of various plug-in electric vehicles (PEVs) in a power network setup. Services are being thoughtful regarding possible overloads & operation dilapidations that could happen in distributed grid setups with various local PEV charging actions. Unrestrained & unplanned PEV recharging can be the reason for voltage fluctuations, increased power losses, & overloads, which are all harmful to the safety & dependability of novel developed smart power grids. Consequently, a concurrent smart load management (RT-SLM) regulating policy is projected & carved for the synchronization of PEV recharging relying on live access (e.g., every 5 min) reduction of the total price of producing the energy plus the related grid power losses. The methodology reduces production cost by integrating time-changing market cost for energy & PEV vendor preferred charging time vicinities based on primacy selection. The RT-SLM algorithm suitably contemplates random PEVs & make use of the maximum sensitivities selection (MSS) improvement. This method allows PEVs to initiate recharging without wasting time considering primacy-charging time vicinities while abiding by the network process standards (like production limits, losses & voltage production). Imitation outputs are offered to show the throughput of SLM for the improved IEEE 23 kV distributed grid system linked to multiple less charge residential topology occupied with PEVs

Aveklouris et.al [15] ponders that a Smart grid is used to recharge electric vehicles in such a fashion that voltage fluctuation stay constrained. The author archetypal this as a set of resource-partaking networks, known as bandwidth-partaking topology in the communication topology literature. The author stress on the resource-distribution topology that is compelled by a set of greedy control norms that can be placed in a distributed fashion. For a huge number of such norms, it characterizes the throughput of the system by a skewed estimate. This results in a class of dynamic equations that consider the stochastic behavior of EVs. The author proposes that the unfathomable fact of these equations is distinctive & can be evaluated by solving a particular ACOPF problem, which confesses a precise convex relaxation. For the set of weighted relative fairness mechanism, the author shows extra appealing factors under the linearized Distflow system, like product form property & fairness of the stochastic model.

3.1 Problem Statement

Smart Grids must acknowledge the concerned needs of all consumers, electric vehicles are particularly stressed due to their mobile & highly diffused nature & possible huge establishments in the forthcoming years would project a key hurdle for forthcoming electricity systems. There is a growing need to change over from petrochemical vehicles to battery-driven vehicles known as electric vehicles (EV) due to the high emission of greenhouse gases & high consumption of nonrenewable resources of fuels based on petrochemical products, these contain motors driven by batteries which are fueled by electricity. Such type of vehicles is classified broadly into three following types.

- **BEV (Battery Electric Vehicles)**: These vehicles have only one source of fuel that is electricity from batteries. These are fully electric-vehicles & contains rechargeable batteries. The advantage is that they don’t produce such damaging releases & dangers produced by petrochemical automobiles. The batteries are charged with the help of external sources. BMW i3, Chevy Bolt, Chevy Spark, Nissan LEAF, Ford Focus Electric are the names of few

- **Hybrid Vehicles**: These vehicles have more than one source of energy, out of which only one works at a time. These vehicles have a process to generate electricity while braking known as regenerative braking. We have 2 subcategories in it: 1) Mild Hybrid Electric Vehicle: A mild hybrid has a big sized starter motor that turns off the engine when the car is not being propelled by the engine, braking or stopped, then restarts the motor quickly & flawlessly. 2.) Plug-in Hybrid Electric Vehicle (PHEV) / Full Hybrid Electric Vehicle: These type of EVs not only have smaller batteries as compared to fully electric vehicles but also has a traditional engine. These are good for short-range distances. Once the battery is discharged the motor shifts to use the petrochemicals for energy & this is what we mean by plugin hybrid. These will also have CO_2 emissions of around 40-75g/km when measured against the European test cycle. Chrysler Pacifica, Ford C-Max Energi, Ford Fusion Energi, Mercedes C350e, Mercedes S550e, etc. are the names of few

- **Extended Range Electric Vehicle (EREV)**: These are similar to Hybrid electric vehicles but are slightly different. The difference being whenever the battery drops to a critical value, they start using petrochemicals as electricity generation to drive motors as well as charge batteries. The advantage is same power & torque as of an electric car, but none of the range problem. The downside being, the electric range is very less than a fully electric car, though it is relatable to that of plug-in hybrid vehicles.

These vehicles require charging at least twice a week & it's impractical to think of going to power grids for charging purposes which is one of the challenges which rises the concept of distributed charging station over the region just like the traditional petrol pumps scattered over the geographical region in order to avoid the queue at the substations(microgrids) or the main grids, even if you decide to reach out to a substation to charge your EVs there is no guarantee whether you'll face a queue or not leading to confusion & later wastage of another important resource i.e. TIME.

3.2 Research Gaps

A lot of studies has been done in the area of the placement of the Charging station (CS) in order to support the framework for the ever increasing number of Electric vehicles since its introduction into the transport sector. In India, the transport industry is one of the important sectors driving economic progression. An estimated figure of 25 million vehicles including three-wheelers, passenger vehicles, two-wheelers, & commercial vehicles were manufactured & put on the road in the financial year 2017, amassing a jump of 5.41% in comparison to the previous fiscal. Nevertheless, it is one of the largest providers of pollution (air pollution in specific), which parenthetically holds the country's capital cloaked in smog for many months every single winter.

As India races towards apocalyptic impending years, the Indian government is now battling to switch to electric cars by 2030. Whereas, the report published by UBS ought to have overly positive take on how the future of electric vehicles will be, one cannot bypass the massive steps taken by the transportation sector has achieved in the last decade or so thus comes the planning & designing of Charging Station placements throughout the region in order to support the numerous EVs soon to be running down the road which requires grid support, which in broad terms referred to as Vehicle-to-Grid (V2G).

As we have known by now that the electricity produced by the Smart grid has a dynamic pricing range which alters during peak hours & off hours there arose the need to understand the complexities in charging & discuss the problem of optimal scheduling of the charging demand of electric vehicles. Research also has been made for shaving the peak in localized load requests which betters their voltage accounts & projected a smart capacity organization arrangement or creating a live synchronized arrangement for recharging of EVs & PHEVs to lower the energy damages in the smart power grid But little to no work has been done to address the problem of "identifying the Charging Station". The challenges like path planning methods & optimizing the charging cycles of batteries are challenging in recent times. But, the increasing presence of EVs has given rise to another challenge –"identifying available CS", which is not acknowledged to its full perspective.

3.3 Research Objectives

In light of the above-discussed research gaps following objectives have been formulated.

- To study various research issues associated with EVs & charging station placement models & policies.
- To develop infrastructure in order to identify the availability status of CS with the help of available infrastructure such as- street lights & ZigBee network.
- To develop a replica management strategy is designed to maintain a global view of CS in a geographical region using a cloud database.
- To develop a geo-clustering application using spatial data present in the cloud database.
- To develop an algorithm to identify & detect the available CS in the region & communicate back to the requesting EV.

3.4 Research Methodology

In our research work, we will be developing an algorithm using Java language, which is an excellent coding language for creating algorithms & testing it out. The dataset required to work on will be gathered using smart street camera APIs that will store & updates the availability status of the charging station every 10 seconds. Hence, our aim is to provide a solution for a better decision making the process in order to identify the available CS in the network. In view of this, the street light fetches the status of CS & forwards it to the cloud database via a ZigBee network. Based on the information stored, the CARaM algorithm returns the available CS to the requesting EV. The whole procedure runs iteratively with the updated information until an available CS is found.

As illustrated in Fig.1.14, we consider a micro-grid (example a university or a town) consisting of a CS, having Street light & a cloud database connected in a wireless network. However, in a scalable CS network scenario, the location of CS is known to consumers, but they are unaware of the availability status. EVs can drive towards it & still can end up in a queue waiting for their turn even when another CS at the same distance is available. Hence, our aim is to provide a solution for a better decision making a process in order to identify the available CS in the network. In view of this, the street light fetches the status of CS & forwards it to the cloud database via a ZigBee network. Based on the information stored, the CARaM algorithm returns the available CS to the requesting EV.

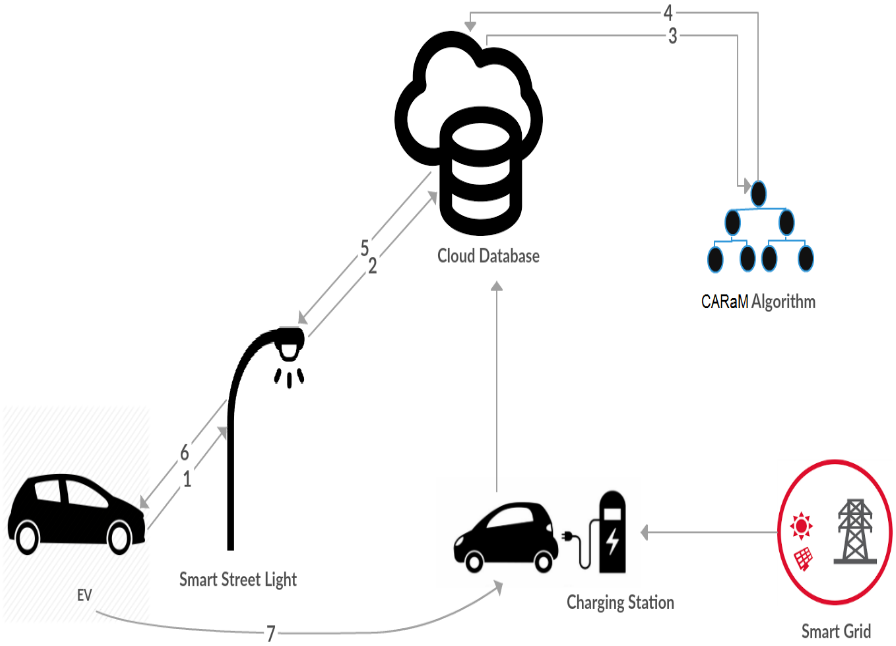

Fig.4.1 Work Flow of the proposed system

Following are the components of the proposed solution:

1. Electric Vehicles: An EV is an automobile driven by a power-driven motor, rather than Internal Combustion Engine (ICE). It runs by means of the power stowed in the electronic batteries. The electronic batteries have to be recharged often by plowing into the direct supply. The biochemical vigor in a fuel cell or machine-driven power in a flywheel is converted into power to run & stored in a storage battery or ultracapacitor. This power is then put in use to drive the motor to steer the wheels & provides force [15]. Regrettably, EVs have a thoughtful demerit that frolicked a big protagonist in the coup by ICE automobiles which are of inadequate variety. It means EVs could only travel 80 kilometers in one charge thus requires better batteries & better placed & available CS to charge frequently. In the proposed solution EVs tend to send requests to base stations in order to acquire the location of available CS. The base stations then address these requests & return the available CS location to its dashboard.

2. Smart Street light acting as base stations: Living in a smart city involves being surrounded by smart devices for almost every hour of the day, one such smart infrastructure is street lights. It is used in our proposed solution to address & respond to the requests of EVs. It is equipped with a camera that is used to identify the status of CS & updates its status in the cloud database. It ensures that a replica of the state of CS is cached inside the cloud database which gets updated in every 10 seconds. Once a request is received by such base station it triggers the cloud storage to retrieve the location of an available CS as presented in fig. 1.15

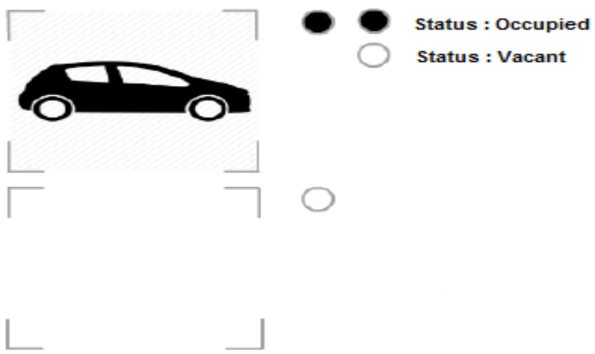

Fig.4.2 Identification of Electric Vehicles at charging station

3. Cloud Database: It is a prototype of computer storage that stores data in logical pools & unlike physical storages, it is much more reliable & responsible for the availability, security, integrity, & accessibility of the data. In our model, the cloud database is used to cache the replica of the status of all CS present in a geographical region. Once the database is triggered to return the location of available CS, our proposed internal CARaM algorithm uses the data available over the cloud to return the closest available CS.

4. CARaM Algorithm: The CARaM algorithm is based on IDDFS that cater to the speed of the breadth-first search (BFS) & efficient space complexity of the depth-first search (DFS). The algorithm takes input from the data stored on the cloud & runs iteratively & recursively until it finds the CS state as free. IDDFS evokes DFS for various depths beginning from an initial value. Whenever a subroutine is evoked, DFS is limited from going past the given depth. So generally we perform DFS in a BFS manner, thus it visits the top-level vertices various times. The end (or maximum depth) level is traversed once, second last depth is traversed two times, & likewise. It turns out to be a space-saving manner although it camouflages as a costly one. In a Binary tree majority of the nodes are at the lowest level. Thus visiting the upper-level nodes multiple

times doesn't account for anything. The intention of using IDDFS & revisiting the upper-level nodes, again & again, is that there is a possibility of a particular CS being engaged in a one-time frame & free on a different time frame. In order to acquire the availability at an instant & not after the complete traversal of the Binary tree, we preferred IDDFS.

5. Charging Station: As mentioned above EVs have limited range, thus travelling for 80 kilometers in one charge. It raises the need for CS & an efficient placement plan in order to avoid detouring. Like any other energy outlets, it too needs an energy wholesaler to disperse electricity to such stations thus comes the role of smart grids. It balances the load of supply-demand in order to distribute energy in a much more efficient way.

6. Smart Grids: Smart grids are a new generation power grid. It is an interconnected network of utilities & consumers that intelligently integrate the actions of all components connected in it, i.e. generators, consumers & those that are capable do both – proficiently provide secure, sustainable & economic electricity. It is an important component of the system model as it generates the source of energy to feed the batteries of EVs on a regular basis & that too providing a 2-way communication to balance the supply-demand between the utility & consumer.

4.1 Proposed Solution

Identifying an available CS is always a headache for the consumers as they might hit into CS which is either engaged or not in function. Discovering available CS in order to reduce the additional fee spent in refueling detours is "discretionary service facility location" problems which this paper tackles. The proposed solution is to use only one communication standard & not multi-standards like WiMAX in one place & ZigBee at another. Such that the problems like interoperability of devices working on different standards & overlays are avoided. The street lights are modified to identify the status of CS & send the same to a cloud database on the ZigBee network thus providing significant bandwidth savings by exploiting the computing & caching resources [16]. Further applying the CARaM algorithm on the information retrieved from the cloud database, the available CS is returned to the requesting EV. Idea is to use the available infrastructure present in mass like the street lights & associate them with a networking technology like ZigBee to address & respond to the requests made by EVs.

Notation	**Description**
α	Request made for attaining the closest available charging station.
β	Used to set the radius in which the search is to be made.
γ	Represents the node (Charging station) spread over the region.
δ	Represents the available Charging station is found.
η	Represents the remaining further nodes to explore in the set radius.
ζ	Represents the remaining node.
κ	Represents the root/base/initial station to begin the search with.
λ	Represents the Available Charging Station.

Table 4.1 List of notations used in CARaM algorithm and their description

4.2 CARaM Algorithm

```
procedure IDDFS(κ)
    for β from 0 to infinity do
        δ,ζ ← DLS(κ,β)
        if δ ≠ null then
            return δ

        else if !ζ then
            return null
        end if
    end for
end procedure

procedure DLS(κ,β)
     if β = 0 then
        if γ is a λ then
           return (,true)
        else
           return (null, true)
        end if
      else if β > 0 then
         η ←  false
      end if
      for all child of n do
           δ,ζ ←  DLS(child,β-1)
           if δ ≠null then
              return (δ ,true)
           end if
           if ζ then
               η← true
               return (null, η)
           end if
        end for
end procedure
```

The aforementioned algorithm is based on IDDFS algorithm. IDDFS calls Depth First Search (DFS) for altered depths beginning from the first value. In every call, DFS is constrained from going past given depth. So mainly we perform DFS in a Breadth First Search (BFS) way. A vital point to understand is, we traverse top-level nodes several times. The last (or maximum depth) level is traversed once, second last level is traversed twice,

& so on. It seems costly, but in reality, it is not so costly. As we know in a tree, most of the nodes are at the leaf level. So it's not substantial if the upper levels are visited several times.

4.3 Working Principle of the Solution/Algorithm

1. Request to acquire the CS is sent to the nearest base station (street light), this message is automatically sent when the system is in reserve state i.e. having low fuel or can be done by the EV arbitrarily. Request accepted for the availability of CS is handled on the principle of FIFO i.e. First in First Out, i.e. the first EV making the request is entertained first. This is maintained by timestamps of a request made to the system.

2. The street light forwards the request to the cloud database where the status of CS is maintained, which includes both acquired & available CS in the cloud database. It gets updated in every 10 seconds.

3. Request at the cloud database triggers the system's algorithm. It examines the nodes of the tree which are actually nothing but the status of CS in a geographical. CARaM algorithm is used in order to search for the goal i.e. an available CS infinitely & recursively through the depths of the tree i.e. radius by revisiting previous states.

4. If the goal is found, the CS changes its status to engaged, & its replica is updated over the cloud database.

5. This process is repeated endlessly every time a request for an available CS is made.

6. After the location of available CS is found it notifies the cars navigation system about the same.

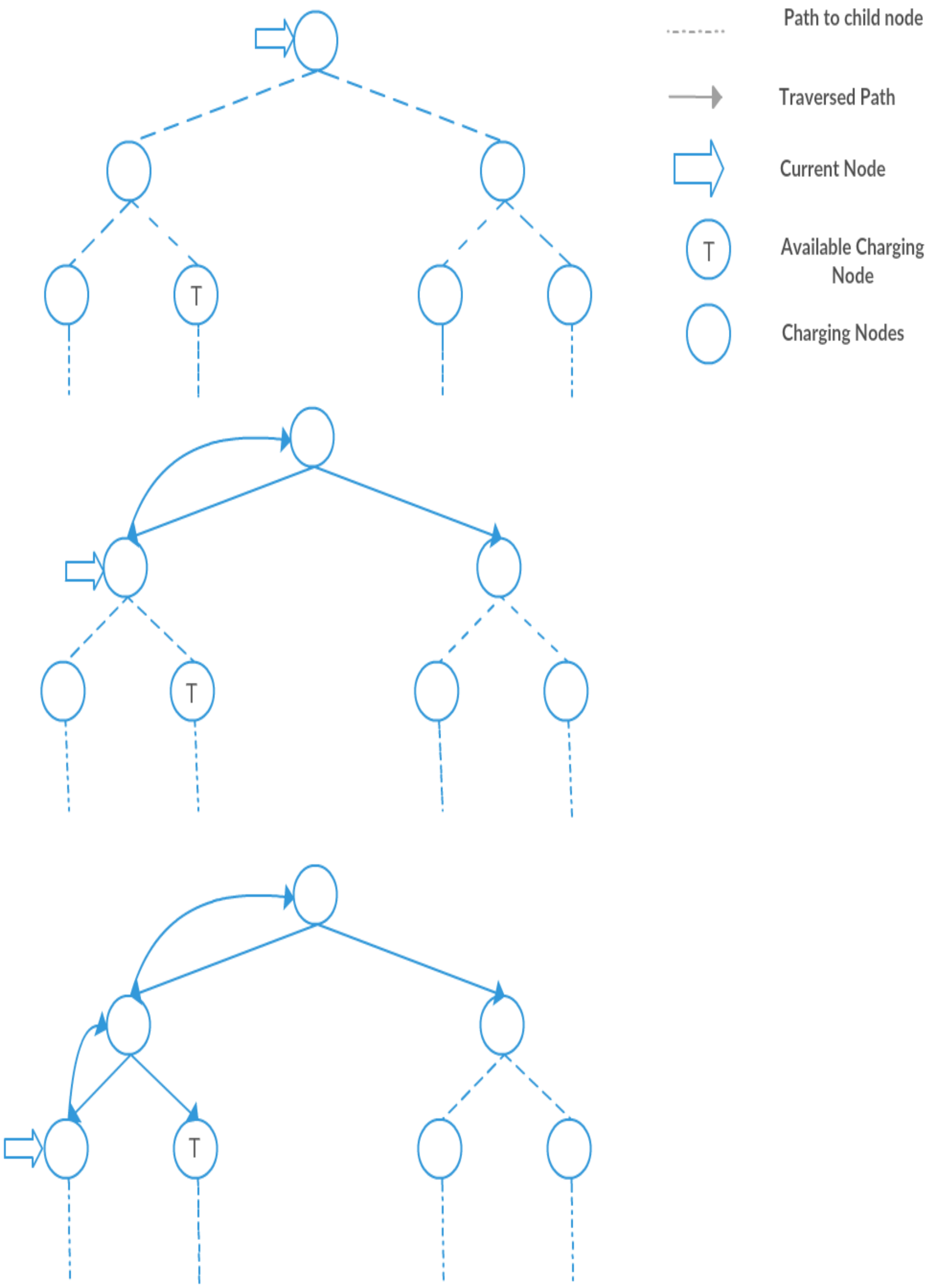

Fig. 4.3 Work Flow of CARaM Algorithm

5.1 Analysis of other searching Algorithms

The data gathered from street lights which are already present in the societal infrastructure is sent to the cloud database for further refining & updating. These data/information holds the status of availability of all charging station presents all around the region. Once the data is acquired, a searching algorithm is required to run over the data to find the goal node i.e. an available charging station within the radius. There were many algorithms in place for searching like Breadth First Search & Depth First Search but we proposed CARaM algorithm in order to enjoy the merits of both previously mentioned algorithms. Let's have a look at the analysis of previously used algorithms.

5.1.1 Breadth First Search Analysis

The idea behind BFS is to traverse the graph/tree in layers, the following instance will clear by what we mean by layer.

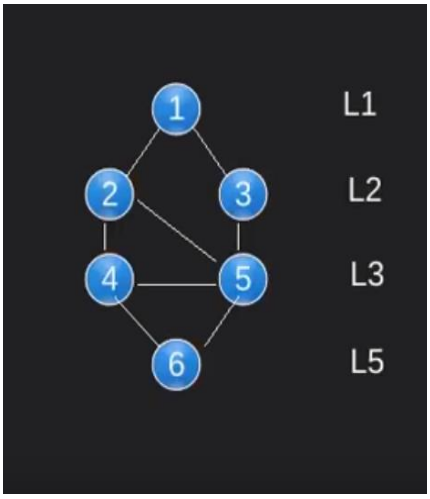

Fig. 5.1 A Graph Instance for BFS

Consider the graph as shown in Fig. 5.1, where node 1 is at layer 1(L1), node 2 & 3 are at layer 2(L2), node 4 & 5 are at layer 3(L3) & node 6 at layer 4 (L4).

If we have our starting vertex as 1, our BFS algorithm will cover the graph as follows, layer 1 will be traversed first then layer 2 then layer 3 & finally layer 4. It is somewhat similar to level order traversal of the tree, however, unlike level order traversal in the tree we have cycles in graphs & each node will be visited infinite times. In order to avoid traversing an already traversed node, we use Boolean visited flag for each node. The flag will be 1 when the node has been visited else 0.

BFS traverse level by level, but entails more space. The space necessary by DFS is O(d) where d is depth of tree, but in the contrary space required by BFS is O(n) where n represents the number of nodes in tree ,the reason behind O(n) is because the last level of tree can hold maximum n/2 leaf nodes & second the last level can hold up to n/4 nodes & in BFS we need to traverse each level in a queue thus resulting in acquiring O(n) space.

5.1.2 Analysis of DFS algorithm

Depth First Search (DFS) travels the graph in depth ward fashion & stack data structure is used to reach the next vertex in order to start a search whenever dead end happens in any reiteration.

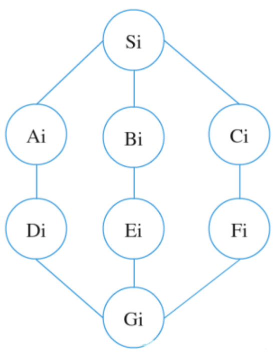

Fig. 5.2 A Graph instance for DFS

As shown above, the DFS procedure travels from Si to Ai to Di to Gi to Ei to Bi first, then to Fi & lastly to Gi. It works on the following rules.

- Rule 1 − Traverse the next unvisited node. Check it as visited. Show it. Push it inside the stack.
- Rule 2 − If there is no adjacent vertex, then pop up the vertex from the top of the stack (this will remove every vertex from the top of the stack, that doesn't have adjacent nodes.)
- Rule 3 – Iterate step 1 & step 2 to the stack is null.

DFS first visit nodes going from one adjacent of root to the next adjacent. The issue with this method is that if there is a node near to root, but not in initial few subtrees traversed by DFS, then DFS arrives at that node very late. In addition to this, DFS might not be able to find the shortest path to a node (in terms of the number of edges) & also acquires the space of O(d)- here 'd' refers to the depth of the tree.

5.1.3 Analysis of CARaM algorithm

With the ever-growing network of EVs, there are a large number of CS to support the same in modern society. Our proposed CARaM algorithm based on IDDFS functions to inform the status of CS to EVs. The trade-off is that iterative deepening revisits the same states many times. Although revisiting the previous states is important in our proposed solution, suppose there are Si states (CS) available in a geographical region & after traversing Sn states we move to Sn + 1 state, then there is a possibility that while we were traversing the Sn + 1 state, Sn state might become available. Thus revisiting the previous states are considered to be important. Another advantage of CARaM algorithm is its quick responsiveness. Early iterations use small values for depth & execute them rapidly. This enables the algorithm to provide early hints of the result nearly instantaneously, after the refinements since the depth increases. This is not the case with DFS, which does not produce instant results.

Algorithm	Depth	Branching factor	Nodes worth of memory used
CARaM	12	10	120
BFS	12	10	123456790123313
DFS	12	10	1111111111111

Table 5.1 Results from different Algorithms

In CARaM search, the nodes situated at depth d are expanded once, those at depth'd-1' are expanded two times, & likewise to the root of the tree, which is expanded d+1 times. So suppose the search tree has a branching factor (b) of 10.Then searching it to d 12 means that there are 1012 which equals one trillion leaves. Iterative deepening uses only about 10 * 12 = 120 nodes worth of memory while searching, but BFS would have to use almost 1010 times more memory. The internal nodes at depth 11 or below have to be revisited multiple times So DFS has to search 13 * 1 + 12 * 10 + 11 * 102 + 10 * 103 + 9 * 104 + 8 * 105 + 7 * 106 + 6 * 107 + 5 * 108 + 4 * 109 + 3 * 1010 + 2 *1011 + 1 * 1012 = 123456790123313 nodes just a little bit more (proportionally) than the 1111111111111 nodes that BFS would visit. Concluding from the table above, if the number of states is growing exponentially with increasing branching factor, then IDDFS based algorithm is much more efficient than BFS or DFS algorithms, as it consumes very low memory as compared to other two.

Chapter 6 Conclusion and Future Scope

6.1 Conclusion

In this thesis, we explore the various research issues associated with the adoption of electric vehicles in the society in the presence of Smart Grid. Then we proceed to understand the challenges offered by the adoption of EVs & reiterate to uncover a challenge that has yet been explored i.e. “Availability of Charging Station”.

We understand the fundamental concept of placement & challenges faced in designing the infrastructure to support the increasing number of EVs in today's & in upcoming years. A variety of research has been done for the problem of CS placement with the charging of EVs & integration into the power system.

The problem of finding parking with smart charging for plug-in hybrid electric vehicles (PHEVs) in microgrids in grid-connected mode is still a challenge to tackle. The aim to allocate CS in industrial microgrids (IMG) is to minimize the system costs in order to ensure a profit to the owner. A vehicle-to-grid control scheme using EVs to contribute to the primary frequency control of the grid in view of the “charging demands” of EVs are some of the primary issues on which research has been done in the extension. But negligible research has been studied to address the latter problem of –“identifying available CS”, which is not acknowledged to its full perspective. It is confronted with the help of available infrastructure such as- street lights & ZigBee network. It has motivated us to find a feasible solution. The Street lights are connected to the cloud database via a ZigBee network to send the status of CS. These are used to provide a global view to return the available CS to the requesting EV to find the solution to identify an available CS.

In this thesis, we present an algorithm named CARaM which is based on the Iterative Deepening Depth-first search. It is proposed to solve the problem of “identification of available CS” among the exponentially growing number of EVs & CS. Based on a five-stage scenario, CARaM algorithm evidently proved to be 17% more efficient than other algorithms in terms of space & time complexity. Since the number of EVs & supporting CS grow in future, the branching factor for the Binary tree to store the status will grow too. Thus requires an algorithm that will traverse all possible nodes & yet put away with a minimum memory to which CARaM has met the standards.

6.2 Future Work

- We can link the status of preferred Charging Stations prior to the navigation system in order to avoid filling in the radius parameter.

- We can improve the searching algorithm’s complexity in order to save more time & space. Since the CARaM algorithm is 17% faster than BFS & DFS & comparatively takes less space there is always a possibility to optimize it furthermore.

- We can also work on the mechanism to enable the braking system in EVs to charge the batteries when EVs go down the slope & reduce battery use.

- We can also work on the mechanism such as Telematics services use onboard transmission setups such as telephone & deliver data like automobile stream of traffic data or climate info, providing distant regulation of automobiles ac or central lock, etc., directing to recover the operation of automobiles.

- We can propose a course exploration function that estimates a best course established on live road-traffic data gathered from the sensor grid containing roadside terminals.

- We can optimize the dispersed lively course supervision setup relying on Wireless Sensor Grids & Open Shortest Route First protocol.
- We can improve route exploration setup that uses info like live road-traffic info & regular info like the proclivity of the course, then estimates a better course considering not course remoteness but fuel feeding by preventing choked plugs or rising hill.
- Improvements on "Multi-objective Route Selection" for automobile Steering Setup Using Genetic Algorithm" is used to find various suboptimal course with least overlying cannot be overlooked. It considers several characteristics of tracks like transitory over the adjacent of hill or stream, having a lower amount of opportunities, etc. The chromosome encrypts one whole answer. The fitness utility is the rundown of the fitness utility w.r.t. separate optimization norm.

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List of Publications

[1] R. Bhatt, C. Garg, H. Singh, N. Kumar, & J.P.C. Rodrigues, "*CARaM: COORDINATED ADAPTIVE REPLICA MANAGEMENT FOR CHARGING STATION*", In Proceedings of 2019 IEEE International Conference on Communications (ICC): Optical Networks & Systems Symposium, Shanghai, China, May 17- May 22, 2019. [**Accepted**]