

An Efficient Itinerary Management Scheme for Electric Vehicles using ACO

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

Masters of Engineering
in
Information Security

Submitted by

Deepika Hooda
Roll no 801433008

Under the supervision of

Dr Neeraj Kumar
Associate Professor, CSED



COMPUTER SCIENCE AND ENGINEERING DEPARTMENT

THAPAR UNIVERSITY

PATIALA 147004

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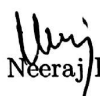
CERTIFICATE

I hereby certify that the work which is being presented in the thesis entitled, "*An Efficient Itinerary Management Scheme for Electric Vehicles using ACO*", in partial fulfillment of the requirements for the award of degree of Master of Engineering in Information Security submitted in Computer Science and Engineering Department of Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of *Dr. Neeraj kumar* and refers other researchers work which are duly listed in the reference section.


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



(Deepika Hooda)

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


(Dr. Neeraj Kumar)
(Associate Professor, CSED)

Countersigned by:


(Dr. Maninder Singh)
Head and Associate Professor
Computer Science and Engineering Department
Thapar University
Patiala


(Dr. S. S. Bhatia)
Dean (Academic Affairs)
Thapar University
Patiala

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Deepika Hooda

ME (Information Security)

801433008

ABSTRACT

Electric grid has been transformed to smart grid by incorporating ICT infrastructure. This transformation of a smart grid from a conventional grid is necessary to achieve environmental targets. Smart grid technology has significantly changed the way of generation and distribution of electricity which not only helps to decrease the demand of power and cost savings, but also can comparably improve the reliability and efficiency of power system. An electric vehicle, a component of smart grid is the vehicle which uses electric motors for moving the vehicle. Itinerary planning of EV is to manage the whole journey without exhausting battery charging. To find the best route in terms of power consumption of EVs, itinerary is planned. Keeping this in mind, we proposed an algorithm which uses ant colony optimization technique to generate the optimized route for electric vehicle to reach its destination from a specific source.

Keywords: Smart Grid (SG), Electric Vehicles (EVs), Plug-in Electric Vehicles (PHEV), Ant Colony Optimization(ACO), Route optimization.

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Chapter 1

INTRODUCTION

1.1 Smart Grid

Conventional grid has been transformed to a grid by included numerous technologies inside, is more efficient grid known as smart grid (SG). This transformation of a SG from a conventional grid is necessary to achieve environmental targets and to make demand response (DR) more significant. It also supports electric vehicles (EVs) as well as generation, distribution and storage efficiency. In brief, it is a technology that allows a two-way communication between the distributor and its end users.

SG technology has significantly changed the way of generation and distribution of electricity which not only helps to decrease the demand of power and cost savings, but also can comparably improve the reliability and efficiency of power system

1.2 Features

1.2.1 Smart Meters

Smart meter is a meter for measuring data in the field of power generation and distribution. Customers can measure their energy consumption by using advanced metric information which we get by smart meters. It helps them to keep track of the power consumption in real time. Normally, it takes certain time or a day to get

the readings. Customers can measure their energy consumption as well as can easily understand billing procedure.

1.2.2 Distributed Generation

Distributed Generation (DG) is generating energy from small sources. Power generation from large scale power plants have some hazardous effects on the environment.

1.2.3 Reliability

Reliability can be defined in many ways. For example, in communication department, reliability is defined as for how much time a particular service is available. In networking it can be defined as successful data packets delivery to the destination. Here, in electricity industry it is measured in terms of power generation and distribution.

1.2.4 Efficiency

Various efforts have been done to make the smart grid more efficient. From the installation of smart grid, number of contributions are done to improve the efficiency of the energy infrastructure such as by including demand-side management, energy distribution to end users could be managed in efficient way.

1.2.5 Security

Grid must be secured so that it can not be attacked by cyber terrorists or hackers. It should not be vulnerable to attacks. If the system is attacked it may lead to total blackout or system failure. So the cyber security is necessary to make the system efficient.

1.2.6 Climate Change

Smart Grid is pollution free grid that is Green Grid. Renewable energy resources such as solar panels, wind mills etc. are used for power generation which is environment

friendly. The zero emissions of harmful gases from an EV contribute a lot to the environment. Smart Energy is Clean Energy.

1.2.7 Demand Response

Demand response allows generators and consumers of energy to take decision in real time. User can easily get the information about the electricity charges at peak and off peak time and he can use power at off-peak time and thereby can save money as prices are low at off-peak hours. User can control his load in order to cut the electricity bills.

1.2.8 Affordability

Fossil fuel prices are increases exponentially day by day which makes it more difficult to get a fossil-fuel driven vehicle. Energy prices will also rise but the consumer will have new options to manage their electricity consumption and thereby can control their electricity bills.

1.3 Electric Vehicles

An electric vehicle, a component of smart grid is the vehicle which uses electric motors for moving the vehicle. An electric vehicle can be powered through a battery. This battery can be recharged or replaced by a new battery at the charging stations in the grid. Charging stations will get energy from the renewable sources such as windmills, solar power system, photo-voltaic cells etc.

First EV was launched in 19th century when electricity was mostly used for running motor vehicles. At that time, the ease of operation and level of comfort it provides, was not possible to achieve by gasoline cars. The internal combustion engine (ICE) has been used in motor vehicles for hundreds of years, but electricity has maintained a commonplace in some other vehicles, such as trains.

1.4 Types of EVs

1.4.1 Plug-in electric vehicle(PHEV)

A PHEV is the motor vehicle which uses its electric for propulsion. The electric motor can be used by the vehicle until battery level reach a predetermined state of charge (SOC) of the battery. At this level the battery needs to be replaced or charged. This battery can be charged from an external source of electricity such as charging stations in the grid.

1.4.2 Plug-in Hybrid EVs

Plug-in Hybrid EV is a full hybrid vehicle which runs on electric mode using large batteries. These batteries can be charged from electric grid. They are also known as grid-able or gas optional EVs. Whenever required they can partly run on electricity generated from local power plants. Some times the internal combustion engine act as a generator to supply power to EVs. The main advantage of PHEVs is that they can be multi-fuel with the electricity generated from diesel or hydrogen.

For PHEVs in charge depleting mode, electricity is the main fuel source since they can store energy which can be used later. Indeed the energy stored is not sufficient to sustain the electric motor as the main driving system, PHEVs also take advantage of regenerative braking.

1.4.3 In-Wheel Motor Hybrid Electric Vehicles

These vehicles are the latest modification in hybrid electric vehicles. In this case, each of the wheels is equipped with a small electric motor. This small electric motors is known as in-wheel motor. Use of this motor will eliminate the need of drive shaft, or other complex components to control braking force individually at each wheel. Application of in wheel motor is not suitable for most of the conventional electric machines due to their low torque density.

1.5 Electric Vehicle vs Conventional Vehicle

Electric vehicles (EVs) are different from conventional vehicles in several ways. First of all, the normal short trips with multiple halt points make the EVs limited range pointless. Secondly, in terms of energy consumption EVS are more efficient than fossil-fuel vehicles. This energy consumption is measured in the situation of continual accelerating and stopping the vehicles. Third the most important one is EVs are environment friendly. EVs uses electric energy which is produced by natural resources so they does not emit any harmful gases. Finally the last one is low operational cost of EVs over conventional vehicles make them more important. Conventional vehicles rely on (ICE) which uses fossil fuels (gasoline or diesel) for motor propulsion. These fossil fuels are millions of years old. These fossil-fuel fuel driven vehicles emits all the harmful gases like carbon dioxide (CO_2), hydrocarbon, sulphur oxides, carbon monoxide and hydrocarbon. The pollution created by these gases have harmful effects on environment and lives. The prices of fossil fuels are skyrocketing. According to an analysis of energy trends, [5] fossil fuel used for transportation is a compelling source of (CO_2) emissions. 70-90% of total toxic gases emissions are the due to the oxidation of carbon during the combustion of fuels of conventional vehicles. For an Electric vehicle which uses electric energy as the fuel,the traveling cost of a unit distance is significantly less than that of a traditional vehicles which were driven by fossil fuel.

1.6 Challenges

1.6.1 High Initial Cost

The major challenge faced is that the initial cost of purchasing the EVs is very high as compared to conventional vehicles. This higher cost is due to the battery system installed in EVs which is very costly. The cost of the batteries will decrease when the production will increase. The cost factor for plug-in hybrid electric vehicles (PHEVs) is higher as it requires an internal combustion engine (ICE) and associated components in addition with the battery pack. Cost will increase by Rs2,40,000 per vehicle after installing ICE system in the EV.

1.6.2 Limited Driving Range and Range Anxiety

Another challenge faced by EV consumer is limited driving range of the vehicle. Driver of the vehicle is always in worried state that he may not be reach his destination with the current battery capacity. Although the average range of a 36kW li-ion battery is 70 kms, many drivers still bothered about limited range of BEVs. PHEVs overcome this range anxiety ,as they can run on alternative fuel when the battery discharged. This is the reason that currently they are more popular among the consumer then BEVs.

1.6.3 Variable Battery Charging Time

Another common concern among consumers is charging time of battery. The required time for charging a battery take 16 hours from a 120-volt electric outlet that may not be convenient for user. Sometimes users may required to install level-2 charger at their homes to charge the BEV. Their system should be upgraded to use 240 volt electric outlet to install the level-2 charger. In case of PHEVs 120 volt outlet is sufficient, so it doesn't require system upgradation. Charging stations with higher voltage can charge the BEV at faster rate. Installation of these units at home will be very costly so these will be available in public places such as shopping centers and

parking areas. Level-1 and level-2 charger are still less expensive than this technology. Moreover, even with these high power chargers, it takes more time to recharge an EV rather than refueling an ICE vehicle.

1.6.4 Manage Charging Infrastructure

Other challenge faced by PEV integration is charging infrastructure. Various benefits provided by residential charging outlets are convenience and access to off-peak hours charging. It will be less expensive to charge the Ev at off-peak hours as well as it enhance the reliability of the grid. Installation of home charging station takes more time and cost. Consumers want to access level-2 charging stations to charge their BEVs which is very costly. The process of charging could be more difficult for those living in multistory buildings, where they may not have reserved parking or the authority to install charging units.

It may be very difficult for those who have no access to residential charging stations such as people living in multi-story buildings. Residential charging provides several benefits to the consumer such as visibility of their vehicles, comfort for early adopters and driving range extension. Challenges faced by non-residential charging infrastructure are placement of charging stations, impacts on peak demand services and the risk of investing in charging infrastructure as the future of the EV market is unknown.

1.6.5 Forecasting Consumer Demand

Success of the EV market greatly depends on the consumer demand. Basically the consumer demand can make or break EVs. While consumer demand is already there and much of it requires specific characteristics. Consumer demand highly depends on price as they would not like to pay more for a good product if they are getting something similar for less price. In addition to price issues, there is lack of knowledge for EVs among consumers which restrict them to buy an EV. Awareness and familiarity with the EVs has to be increased among the consumers. Although, initially there

would be high growth in the sale of EVs but it is not sure that it will be maintained. In order to increase the sale, EVs will need to enhance the technology, driving range and charging infrastructure.

1.6.6 Manage Vehicle Charging

Balanced supply of electricity with demand is the another major challenge for the successful integration of EVs with electric grid. Deployment of large number of EVs could put stress on the grid as it increases electricity demand. This stress depends on the output of charging station whether it is level-1,2 or 3, the greater the output, quickly the next vehicle gets turn for charging. It has been concluded in a study conducted by the Institute of Electrical and Electronics Engineers (IEEE) that un-managed charging of EVs has negative effects on the electricity distribution system. To manage the electricity demand, charging price can be reduced during off-peak hours. Consumer can save money by charge their vehicle at night and use it in peak hours. During peak hours electricity generation and distribution must be higher to fulfill the consumer demand.

Chapter 2

Literature Survey

2.1 Smart Grid

Conventional grid has been transformed to a grid by included numerous technologies inside, is more efficient grid known as smart grid (SG). This transformation of a SG from a conventional grid is necessary to achieve environmental targets and to make demand response (DR) more significant. It also supports electric vehicles (EVs) as well as generation, distribution and storage efficiency [1]. In brief, it is a technology that allows a two-way communication between the distributor and its end users.

2.1.1 Importance of Smart Grid

SG technology has significantly changed the way of generation and distribution of electricity which not only helps to decrease the demand of power and cost savings, but also can comparably improve the reliability and efficiency of power system [2]. Like Internet, the SG also consist of computers, controls, automation, and new technologies and devices which works together, but here these technologies works with the grid which is fully electric, to response in digital terms to our electric demand.

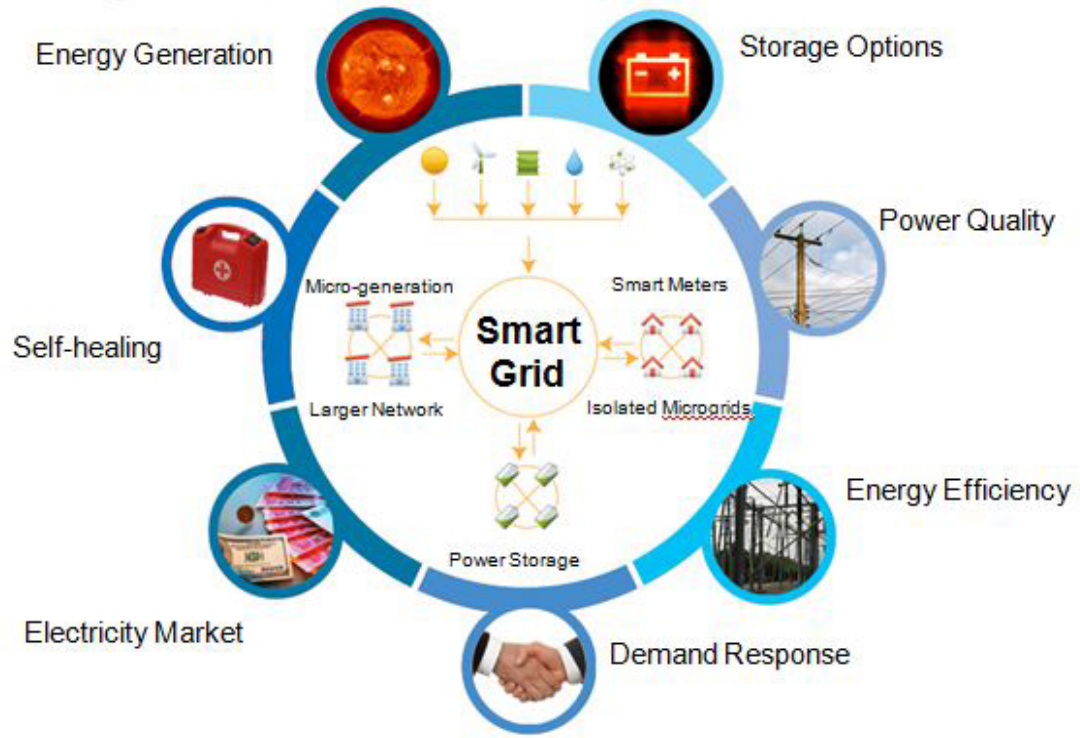


Figure 2.1: Smart Grid

2.1.2 Components of Smart Grid

Automated appliances, smart meters, distributed substations, smart distributors, smart power generation systems are the different components of smart grid [3]. An electric vehicle, a component of smart grid is the vehicle which uses electric motors for moving the vehicle. An electric vehicle can be powered through a battery. This battery can be recharged or replaced by a new battery at the charging stations in the grid. Charging stations will get energy from the renewable sources such as windmills, solar power system, photo-voltaic cells etc.

2.2 Electric vehicles

Electric vehicles (EVs) are different from conventional vehicles in several ways. First, EV battery capacity remains low that makes the driving distance comparably limited due to which it may be required to recharge the EV several times during the journey.

Secondly, in terms of energy consumption EVs are more efficient than fossil-fuel vehicles. This energy consumption is measured in the situation of continual accelerating and stopping the vehicles. Third the most important one is EVs are environment friendly. EVs uses electric energy which is produced by natural resources so they does not emit any harmful gases. Finally the last one is low operational cost of EVs over conventional vehicles make them more important.

According to an analysis of energy trends, [5] fossil fuel which we use for transportation is a compelling source of (CO_2) emissions. 70-90% of total CO_2 emissions are the due to the oxidation of carbon during the combustion of fuels of conventional vehicles. The oxidation of carbon during combustion of fuels of conventional vehicles is responsible for 70-90% of total CO_2 emissions. For an EV which uses electric energy as the fuel, the traveling cost of a unit distance is significantly less than that of a traditional vehicles which were driven by fossil fuel. Taking an example of BYDe6 EV, its electricity consumption for distance of 100 km is only 30 kWh, which is very less when compared with fossil fuel driven vehicle [8]. Accordingly, it is very familiar that the EVs will be broadly applied in the logistics system.

2.2.1 Limitations of EVs

The drawback of the EVs is that its driving range is relatively exceedingly low when compared with the internal combustible vehicles, therefore becoming the ultimate hurdle in its development. It is a valid point where we consider that the drivers live in the recurring threat of being unable to reach their destinations, an example being restricted movements between cities afar ,using the electric vehicles.

In recent years, some policies were defined by several countries around the world. The purpose of these policies was to enhance the advancement and deployment of EVs[9]. For example, a project named as ten cities thousand vehicles program was initiated by government of china and also gives platform to popularize the development of EV technology and its use by the customers. By the end of 2011, they installed 245 charging stations and 13,256 charging piles in china. Moreover, it was

also confirmed that 905 charging stations and 2,33,000 charging piles would be installed in the near future [10].

2.2.2 Battery Management

In [11], an intelligent energy management strategy for EVs was proposed. It takes into account various parameters such as vehicle location, current traffic conditions and road characteristics and then plan the itinerary for the trip. The design of the energy management of the batteries is one of the critical consideration in the development of EVs. It determines how the energy should be generated and distributed to the end users so that it can be used efficiently. In [12]-[15] several energy management schemes has been proposed from control and optimization prospect.

In [13], Gong *et al.* had proposed a new approach for better power management of PHEVs. The driving cycle model was based on the past traffic information in the charge depletion mode. In order to get the optimized solution dynamic programming algorithm was applied. For different situations Driving cycle model was approached differently. For example, acceleration or deceleration rate and avg waiting time were used used for normal roads, while for highways past data were used.

In [14], Erol-Kantarci *et !al.* had developed a Home Gateway and Controller (HGC) device. This device controls the charging/discharging modes of PHEV by communicating with them. Also by using this device consumers can increase their savings because it coordinates with the power supply of solar panels and here can save minimize the use of PHEV battery. HGC can also be used in smart homes to schedule the energy consumption of smart appliances by communicating with the controller of the solar panels.

In [15], Freige *et al.* had proposed a battery transfer algorithm for EVs based on the intelligent management model. It uses Ant Colony Optimization and considered dynamic traffic congestion. In[16], an optimization tool was developed to recognize the charge pattern of PHEVs. A simple power-train model was used to determine the fuel and energy consumption characteristics.

2.2.3 Route Optimization

In [17], Jin *et al.* had presented an optimization algorithm for scheduling problem of EV charging. The objective of the study is to minimize charging cost and maximize the utilization of renewable energy. They have used multi-queue model to complete different charging request of EVs.

In [18], Dantizing and Ramser *et al.* first proposed the vehicle routing problem (VRP). There can be different objectives of the VRP such as find the route with minimum distance or minimum cost or minimum driving time by the fossil-fuel vehicles. The different constraints could be loading limit of vehicle, type of vehicle or time windows limit, etc. The route optimization of EVs is comparatively the new topic for research.

In [22], a model to find the optimized route of the gasoline or diesel powered vehicles is presented. Aim of this optimization was to minimize the distance traveled by vehicle and eliminating the risk of running out of fuel considering the alternative supply of energy. The partial application of this model can be used to find the optimized for an EV.

In [23], Lin *et al.* proposed an Electric Vehicle Routing Problem. The objective of this research is to minimize the travel time, energy and number of EVs. The proposed model considered the limited battery capacity and unrestricted battery charging infrastructure at charging station. Anyhow, costs of charging was not considered in this model.

In [24], Chale-Gongora *et al.* shows the electric vehicle network and focus on the vehicle routing model. Consumption of energy and charging time were considered to assure that EV could be used beyond its limit by using the best path from a source to destination. Factors like charging cost, road tax and distance of a destination from a specific source are still not covered in recent papers.

2.2.4 Driving Style

In [25], Bingham *etal.* focused on the behaviour/driving style of the driver on state-of-charge (SOC), driving range and energy consumption of the EVs. They have shown that driving at normal speed can save 30% of energy. The results shows that by driving at constant speed or minimizing the acceleration deceleration in the driving cycle can save a good amount of energy. 9

In [26], Neaimeh *etal.* presented an analysis which shows that driving range of the EVs can be extended by calculating the minimum energy route to destination. This route is based on the topology and traffic conditions of the road network.

Based on such discussions, we develop an efficient plan using the ACO algorithm that calculates the optimized route from a specific source and reassure the driver that he will reach his destination on time. We have assumed that Internet (GPS) could be used by the driver of the vehicle to get the information like current weather condition, current traffic, distance between his current position and charging station as well as the position of charging stations. Applications like CarStations[27] or ChargeMap[28] can be used to display the positions of charging stations on a map. The roads connecting service stations through the route to the destination are an integral part of this plan. With differentiating prices and recharging speed at the different stations. Our main focus are the EVs even though we do take consider the hybrid vehicles too. The autarchy/autonomy of the EVs is fragile at many levels and factors. There a number of external and internal parameters that go into driving the EVs and evaluate its energy consumption. The algorithm presented in this paper provides the driver with a dependable plan of driving, and for this success we have to be grateful to the network analysis and autonomy calculations of the project.

Chapter 3

PROPOSED WORK

3.1 Research Motivation

According to an analysis of energy trends [29], fossil fuel which we use for transportation is a compelling source of (CO_2) emissions. 70-90% of total CO_2 emissions are due to the oxidation of carbon during the combustion of fuels of conventional vehicles. These are the reasons for which EVs could be used to improve the world policies for continuous advancement, in ecological as well as energy related sides by minimizing the emissions of CO_2 (and other harmful gases such as Nitrogen Oxide (NO_2), Hydrocarbon (HC), and Carbon Monoxide (CO)). For an Electric vehicle which uses electric energy as the fuel, the travelling cost of a unit distance is significantly less than that of a traditional vehicles which were driven by fossil fuel. The use of electric vehicles has a positive impact on both economy and ecology, particularly the climate policy and tensions on oil that EVs allow a considerable reduction in CO_2 emissions by private transport. Indeed, by using electric vehicles we can achieve energy independence because they use electricity generated from natural resources rather than relying on foreign oil. Moreover, electricity is cheaper than fossil fuel used by conventional vehicles. Natural renewable resources, such as solar energy or wind power can be used to generate electricity and therefore helps to control pollution. Moreover, EVs consumes less amount of energy than conventional vehicles and hence EVs are more efficient.

In [17], Dantizing and Ramser *et al.* proposed vehicle routing problem that determines shortest path for fossil-fuel driven vehicles. A study has been done on fast charging mode of EV which different from normal charging mode[13]. In [23], H. G. Chale-Gongora *et al.* proposed an Electric Vehicle Routing Problem. The objective of this research is to minimize the travel time, energy and number of EVs. The proposed model considered the limited battery capacity and unrestricted battery charging infrastructure at charging station. Anyhow, costs of charging was not considered in this model.

3.2 Gaps in Study

SG technology has significantly changed the way of generation and distribution of electricity which not only helps to decrease the demand of power and cost savings, but also can comparably improve the reliability and efficiency of power system. An electric vehicle can be powered through a battery. This battery can be recharged or replaced by a new battery at the charging stations in the grid. For an EV which uses electric energy as the fuel, the traveling cost of a unit distance is significantly less than that of a traditional vehicles which were driven by fossil fuel. But the drawback of the EVs is that its driving range is relatively exceedingly low when compared with the internal combustible vehicles, therefore becoming the ultimate hurdle in its development. It is a valid point where we consider that the drivers live in the recurring threat of being unable to reach their destinations, an example being restricted movements between cities afar ,using the electric vehicles. For an electric vehicle, there are number of paths to reach a specific destination from any point. But these paths may take distance/cost which is not affordable by the driver. So, an optimized route is required in terms of distance and cost through which an electric vehicle can reach its destination without exhausting battery capacity.

3.3 Problem Defination

After studying the problem in the existing domain, this conclusion has been derived that still there are number of flaws in the management of EVs. Without management of EVs it would be difficult to reach the destination on time. Driver should choose the path according to his time and pocket. Thus seeing mentioned gap, it was decided to look into the problem of finding optimized route from a source to destination. To find the optimized route we need two parameters which are distance of the path and charging cost of charging stations.

3.4 Objectives

- To increase the driving range of EVs.
- To design an algorithm which finds the optimized route from source to destination.
- To minimize the cost of the journey.

3.5 Methodology

3.5.1 Ant Colony Behaviour

Ants are social insects which lives in colonies. They do not need any planning or control for a journey. All the thanks should be given to their mutual collaboration. Their potential to find the shortest route from their colony to food is the interesting fact of their complex behaviour. Some kind of ants deposit a kind of substance called pheromone on path when move from anthill to food source.‘If there is pheromone on the path then they follow the path with maximum value of pheromone otherwise they move in random direction.

Figure 3.1 shows how the shortest path to the food source found by ants. Food source is marked with G and their nest A. So after reaching at position B the ants have to take decision to turn left or right. A higher level of pheromone on the

left path means a higher probability to turn left. For the first ant reaching point B, the probability to turn left or right is equal. The first ant following the path $B \rightarrow I \rightarrow D$ will reach D before the ant following the path $B \rightarrow C \rightarrow D$, because the path $B \rightarrow I \rightarrow D$ is shorter than $B \rightarrow C \rightarrow D$. Again at position D ants have to take a decision whether to turn right or left and similarly ant following the path $D \rightarrow F \rightarrow G$ will reach to food source before the ants following the other path. As a result the ant returning from G will find the high level of pheromone on path $G \rightarrow F \rightarrow D \rightarrow B \rightarrow A$, because by chance half the ants selected this path to reach the G from A. So, they will prefer path $G \rightarrow F \rightarrow D \rightarrow B \rightarrow A$. Therefore, the number of ants following path $A \rightarrow B \rightarrow D \rightarrow F \rightarrow G$ per unit of time will be higher than the number of ants following $A \rightarrow B \rightarrow C \rightarrow D \rightarrow F \rightarrow G$. Due to this the quantity of pheromone on the shortest route would grow quickly. The final result is that very quickly all ants will choose the shorter path.

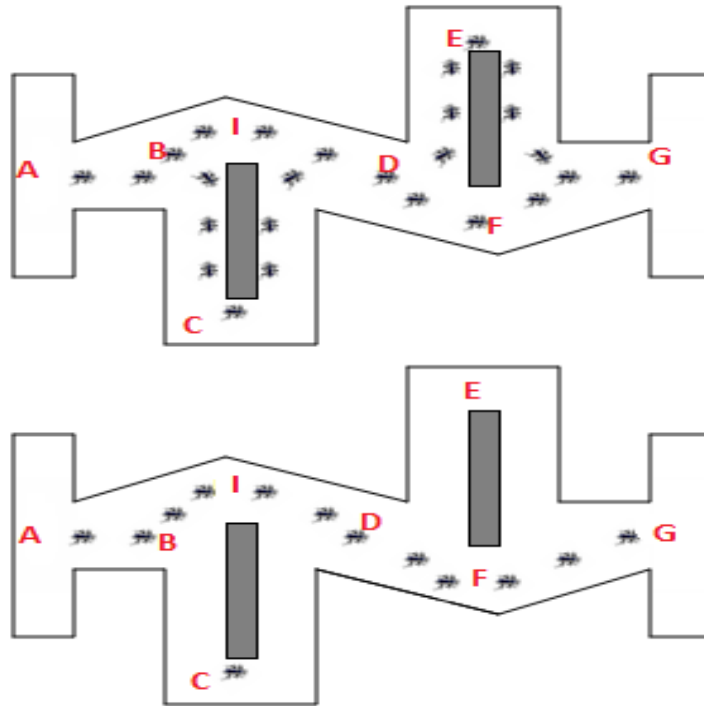


Figure 3.1: Ant Colony model

3.5.1.1 ACO Algorithm

ACO is composed of two phases. In the first phase, a set of ants is placed at the source node which travels to the destination node by choosing different paths. Then, in second phase, the ants move back from destination node to the source node and thereby updating the pheromone values of the paths. For better understanding there is an example of a graph. Formally a weighted directed graph is defined as $G(V, E, W)$, where:

- V is the set of nodes $v_1, v_2, v_3 \dots v_n$.
- E is the set of edges which defines the distance between two nodes v_i and v_j .
- W is the pheromone weight.

Every node v_i in the network has a set of neighbours defined as,

$$N(v_i) = \{v_j \mid v_j \in V, d_{ij} > 0\} \quad (3.1)$$

Where d_{ij} is the distance between v_i and v_j . When the ant m is at node v_i , next node $v_j \in V$ will be selected with probability P_{ij}^m , which is calculated by applying transition probability formula as follows:

$$P_{ij}^m(t) = \frac{[\omega_{ij}(t)]^\alpha * [\gamma_{ij}(t)]^\beta}{\sum_{v_l \in N(s_i)} [\omega_{ij}(t)]^\alpha * [\gamma_{ij}(t)]^\beta} \quad (3.2)$$

where,

- $\omega_{ij}(t)$ is the amount of pheromone deposited between nodes i and j .
- α is a parameter which controls the relative weight of pheromone.
- $\gamma_{ij}(t)$ is the location function between i and j .
- β is a parameter which controls the influence of distance.

$$\gamma_{ij}(t) = \frac{1}{d_{ij}} \quad (3.3)$$

where.

d is the distance between i and j .

After completing the tour, each ant lays pheromone on the respective edges included in their respective tours. The rules to update pheromone value on each edge.

Each ant lays pheromone on the respective edges after the completion of a tour. Now when m ants go back to the source node they will follow the route with maximum pheromone value. Pheromone values will be updated in the following way.

$$\omega_{ij}(t) = (1 - \rho) \cdot \omega_{ij}(t) + \Delta\omega_{ij}(t) \quad (3.4)$$

$$\Delta\omega_{ij} = \begin{cases} \frac{1}{L^m}, & \text{if } m \text{ passed from } v_i \text{ to } v_j \\ 0, & \text{otherwise} \end{cases} \quad (3.5)$$

where,

ρ is the evaporation rate. we have taken value of ρ as 0.1 from[].

L^m is the length of the tour found by m ants.

As shown in equation (3.5), the amount of pheromone laid by each ant is inversely proportional to the length of the tour. Therefore, the edges with large amount pheromone is the shortest tour, and vice versa. Each ant starts the search for a new round tour based on the updated pheromone information.

3.6 Designed Solution

In the proposed model we have found the optimized route using Ant Colony Optimization (ACO) technique. The ants are nothing but the objects associated with the vehicles. The optimized route is the shortest path with minimum cost from the source to destination. We have considered a network, a weighted undirected graph(V,E,C) in fig. 3.2 where,

- V is the set of nodes $v_1, v_2, v_3 \dots v_n$ which act as charging stations except source and destination nodes.
- E is the set of edges which defines the distance to reach v_j from v_i .
- C is the cost of charging the battery which is different at various stations.

There is a source node S and destination node D . Our objective is to find the trip from S to D with minimum distance and minimum cost.

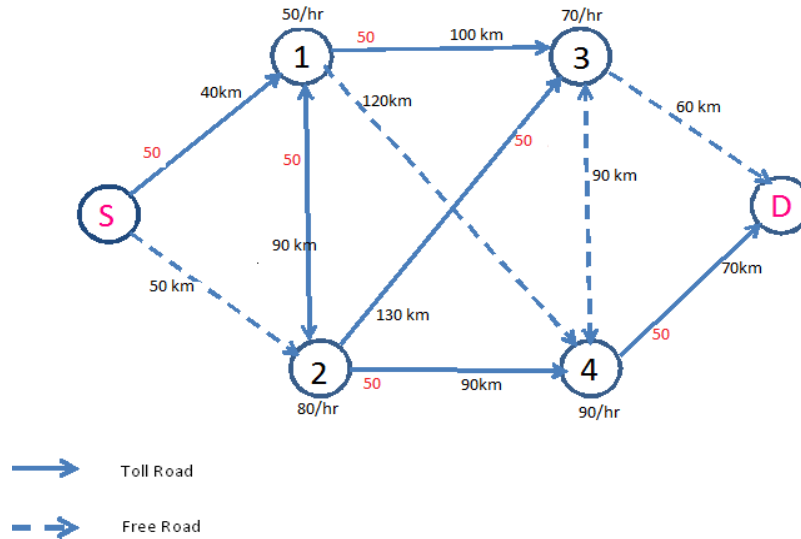


Figure 3.2: Road Topology

We took various parameters to find best path from the source to destination. These parameters are as follows:

- Number of nodes(v_1, v_2, \dots, v_n).
- Type of road(Free road/Toll road).

- Distance between two nodes.
- Driving time to reach node j from i.
- Cost of battery charging at different charging stations.
- Type of battery we have used in EVs.
- Toll price of each road.
- Probability function.

Every node v_i in the network has a set of neighbours defined as,

$$N(v_i) = \{v_j \mid v_j \in V, d_{ij} > 0\} \quad (3.6)$$

Where d_{ij} is the distance between v_i and v_j . when the vehicle is at node v_i , next node $v_j \in V$ will be selected with maximum probability P_{ij} which is calculated by applying transition probability formula as follows

$$P_{ij} = \frac{[\psi_{ij}]^\alpha * [\eta_{ij}]^\beta}{\sum_{v_l \in N} [\psi_{il}]^\alpha * [\eta_{il}]^\beta} \quad (3.7)$$

where ψ_{ij} is a cost function defined by

$$\psi_{ij} = \frac{1}{c_{ij}} \quad (3.8)$$

and, η_{ij} is the location function defined by

$$\eta_{ij} = \frac{1}{d_{ij}} \quad (3.9)$$

c_{ij} is the cost to reach vertex v_j from vertex v_i and d_{ij} is the distance from the vertex v_i to v_j . Now α the parameter to control the influence of cost and similarly β is the parameter to control the influence of distance.

By using the equation(3.7), we have constructed the table given below. —

We have constructed the graph which shows the optimized route from source to destination by using the table. We took the source node and find the probabilities to reach each one of its neighbors. Select the path with higher probability. Now, from the selected vertex find the probabilities to all of its neighboring vertices and

Table 3.1: Probability Comparison

Node i	Node j	Road Type	Distance (kms)	Charge cost (per hr)	Battery type	Toll rate (INR)	Total cost (INR)	Prob (P_{ij})
S	1	Toll	40	50	li-ion	50	100	0.55
S	2	Toll	60	80	li-ion	0	80	0.46
1	2	Toll	90	80	li-ion	50	130	0.33
1	3	Toll	100	70	li-ion	50	120	0.32
1	4	Free	120	90	li-ion	0	90	0.35
4	3	Free	90	70	li-ion	0	70	0.36
4	D	Toll	70	0	li-ion	50	50	0.64

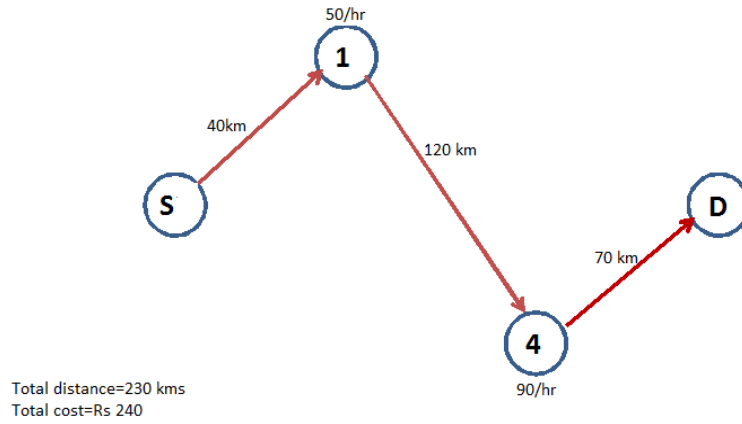


Figure 3.3: Best Path

choose the one with highest probability. Follow the same procedure till we reaches the destination.

3.6.1 Algorithm

Algorithm 1 Optimization algorithm for route optimization

Initialize : i, j, S count, max,m[100][100]

Input: n, dist, cost

Output: probability(p_i,j)

```
1: Function prob(m[0][0])
2: for (i=1; i<=n; i++) do
3:   for (j=1; j<=n; j++) do
4:     if (m[i][j]  $\neq$  0) then
5:       x= compute Probability using Eq. 6
6:       node[count++].  $\phi_i=i$ 
7:       node[count++].  $\phi_j=j$ 
8:       node[count++]. value=x
9:     end if
10:  end for
11: end for
12: sort(node· value)
13: return i,j
14:  $\forall$  i,j, prob(m[a][b])
```

The above algorithm gives us the optimized route from source to destination. First of all we have initialized the variables used in the algorithm. i and j belongs to nodes of a graph, count keep track of the nodes, S is structure that consist of three variables(value, i_index, j_index,), and a matrix m[][] which shows the connectivity of the nodes. If m[i][j] is 0, it means there is no path from i to j and 1 means there is a path. Number of nodes, distance and cost are the input for the algorithm whereas probability is the output. Now line 1 defines a function 'prob' which takes base address of the matrix m as the arguments. Line 4 checks whether there is a path from node i to j and line 5 computes the probability of the path from node i to j and store it in variable x. Line 6 stores the index of i and similarly line 7 stores the index of j. We store the value of x at line 8. Line 12 sort the nodes according to value of x. Line 13 returns the value of i and j associated with x. Line 14 calls the function prob for all i and j.

Chapter 4

RESULTS AND DISCUSSIONS

4.1 Implementation

MATLAB r2016a was used to find the optimized path from a source to destination. First of all we have created a graph in MATLAB. This graph represents a road topology. Here, all the nodes except source and destination are charging stations all of which have some charging cost. Charging cost depends on the time taken by the EV to recharge its battery. Edges are paths from one node to other. Some numbers are assigned to these edges which are the distance from one node to other.

As shown in Fig.4.1, there is a road topology where, S is source and D is destination. All the other node are charging stations. Now to find the optimized route, an route optimization code was written in MATLAB as follows.

Fig. 4.2 and 4.3 are the screen-shots of the code written in MATLAB. In the code written in fig. 4.2, two matrices are initialized, one for distance and other for cost of the paths. After that distance and cost function were calculated. Now, matrix m is defined where m_{ij} is 1 if there is a path from i to j otherwise, m_{ij} is 0. Here, we have assumed influence factor of cost as well as distance 1. It means both of these are equally important to find the optimized route. Now, probability of choosing a path is calculated if there is path from i to j that is, if m_{ij} is 1. To find the probability some other parameters were also calculated.

In fig. 4.3 it is shown that the path with the maximum probability should be

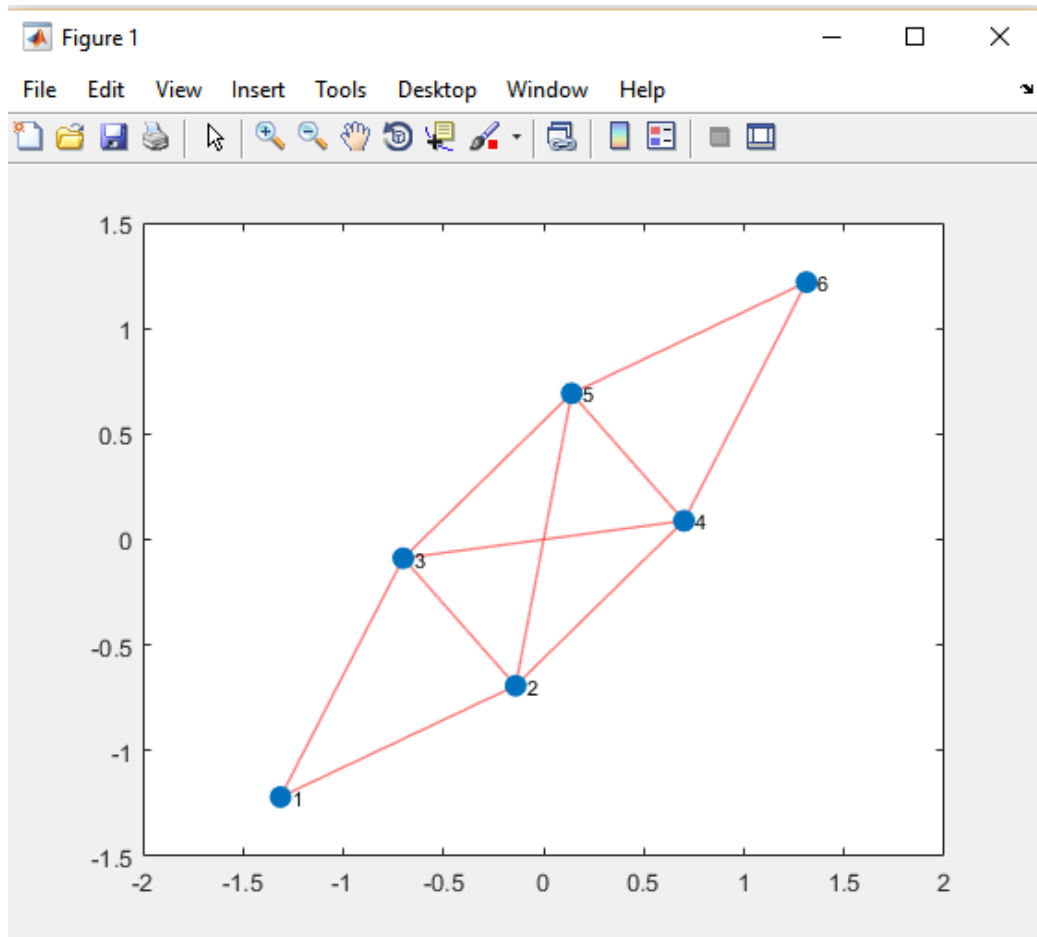


Figure 4.1: Road Topology

The screenshot shows the MATLAB R2016a editor interface. The main window displays the code for 'thesisgraph.m'. The code includes initialization of variables, matrix definitions, and nested loops for calculating probabilities. A workspace table is visible at the bottom left, showing the values of variables alpha, beta, dist, eta, i, and l.

```

1 - clear;
2 - close;
3 - dist= [inf 50 60 inf inf inf; inf inf 90 100 120 inf; inf 90 inf 130 90 inf; inf inf inf inf inf];
4 - cost = [inf 100 200 inf inf inf; inf inf 130 120 90 inf; inf 100 inf 120 140 inf; inf inf inf inf inf];
5 - alpha=1;
6 - beta=1;
7 - phi= 1./dist;
8 - eta= 1./cost;
9 - m = [0 1 1 0 0 0; 0 0 1 1 1 0; 0 1 0 1 1 0; 0 0 0 0 1 1; 0 0 0 1 0 1; 0 0 0 0 0 0];
10 - n=6;
11 - sum=[0 0 0 0 0 0; 0 0 0 0 0 0; 0 0 0 0 0 0; 0 0 0 0 0 0; 0 0 0 0 0 0; 0 0 0 0 0 0];
12 - sum1=0;
13 - maxprob=0;
14
15 - for i=1:n
16 -     for j=1:n
17 -         if (m(i,j)~= 0)
18 -             sum(1,:) = ((phi(i,:)).^alpha).*((eta(i,:)).^beta));
19
20 -             for k = 1:n
21 -                 sum1 = sum1 + sum(1,k);
22
23 -             P(1,j) = (((phi(1,j)).^alpha).*((eta(1,j)).^beta))./sum1;
24 -             end
25 -         end

```

Name	Value
alpha	1
beta	1
cost	6x6 double
dist	6x6 double
eta	6x6 double
i	6
l	2

Figure 4.2: MatLab Code

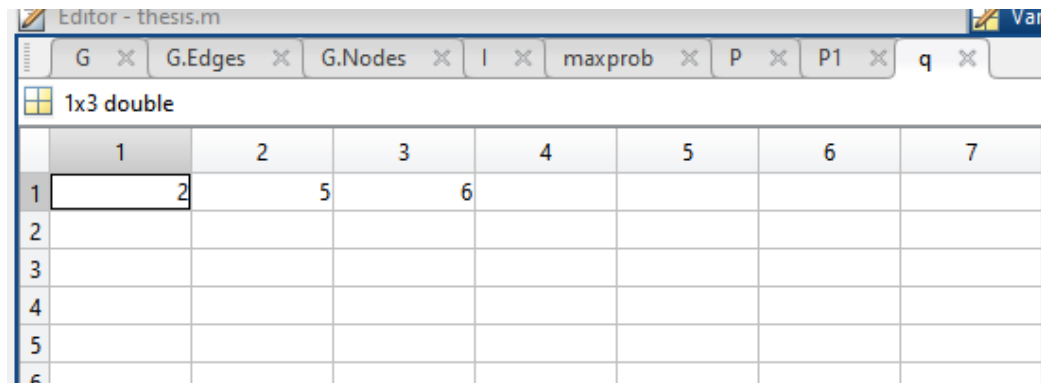
```

31 - end
32 - [maxprob,I] = max(P);
33 - q=[I];
34 - for i=I:n
35 -     for j =I:n
36 -         if (m(i,j)~= 0)
37 -             sum2(i,:) = (((phi(i,:)).^alpha).*((eta(i,:)).^beta));
38
39 -             for k = I:n
40 -                 sum12 = sum1 + sum(1,k);
41
42 -             P1(1,j) = (((phi(I,j)).^alpha).*((eta(I,j)).^beta))./sum12;
43 -             end
44
45
46
47 - end

```

Figure 4.3: MatLab Code

selected. To do this we took an array which holds the value of the end node of path having maximum probability. Next iteration would start from current node stored in an array. Iterations would be applied till it reaches the last node that is destination node. At the end, q was holding multiple values which are the nodes of the graph. These nodes should be connected to find the optimized route.



The screenshot shows a MATLAB editor window titled "Editor - thesis.m". The variable browser on the left indicates a 1x3 double array named "q". The main workspace area displays the following table:

	1	2	3	4	5	6	7
1	2	5	6				
2							
3							
4							
5							
6							

Figure 4.4: Array q

4.2 Results

Fig. 4.4 is the screen-shot of the data stored in array q . We created the graph by connecting all the nodes stored in the the array q . This graph is the optimized path from source to destination. Keep in mind that source node is not there in the array. The reason for this is that we have already started the iteration from source node. So, the source node is the starting node from where first probability function was calculated

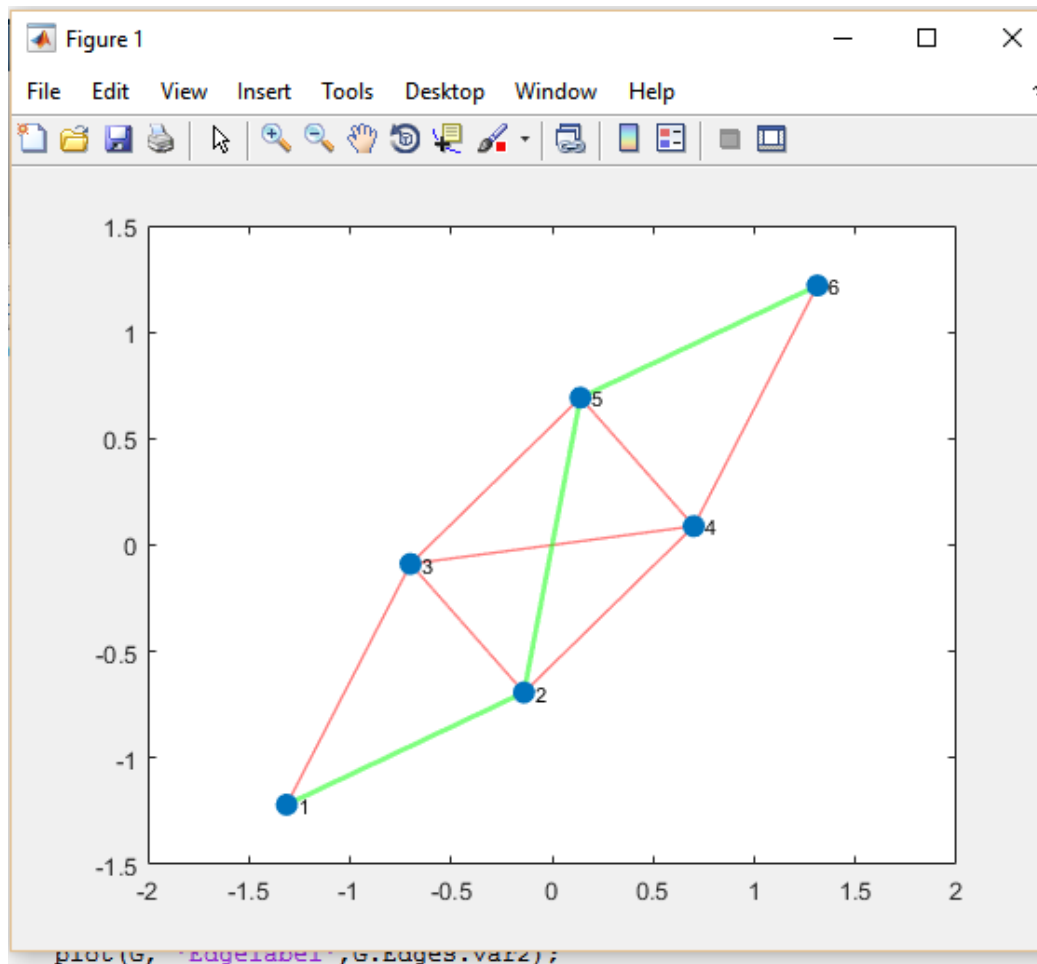


Figure 4.5: Optimized Path

4.3 Comparison

The optimized route for an EV was calculated using many techniques which are different from ACO. The parameters or constraints used by these techniques or algorithms are different. Table 4.1 shows different parameters considered by various algorithms. Only distance was minimized to find the optimized route using Dijkstra’s algorithm. Similarly, in Bellman ford also, only distance was considered. But using ACO three parameters were considered to get the optimized route from a source and destination. Although the time complexities of all the algorithms are same, but the number of parameters are more in ACO. It means if dijkstra’s or bellman ford algorithm use all these parameters for route optimization then their complexities will also be increased. Therefore after comparing with these algorithms it is found that in the same time ACO gives best results. It not only give shortest path but also minimize the cost and time of journey.

Table 4.1: Comparison of different algorithms

Algorithm Name	Constraint 1	Constraint 2	Constraint 3	Battery Type	Time Complexity
Dijkstra’s	Distance	-	-	Li-ion	$O(n^2)$
Bellman Ford	Distance	-	-	Li-ion	$O(n^2)$
ACO	Distance	Cost	Time	Li-ion	$O(n^2)$

Chapter 5

CONCLUSION

5.1 Conclusion

One of the severe problem faced by EVs drivers is addressed in this work i.e. to find the optimized route of a journey. Unlike the approaches given earlier, a new idea was presented on basis of distance and charging cost of the charging stations. In this work, it is shown that driver can choose the optimized path to reach a specific destination without exhausting battery capacity. It depends on driver to choose the influence factor of the distance and cost. As per best of my knowledge no work has been done in this particular domain, i.e., route optimization using ACO technique. This work also addressed drivers of EVs to educate more about management of their journey to save money and time.

5.2 Future Scope

There are numerous future works in this domain. In this work we have used ACO technique to find the best route. But still some other optimization techniques can be used in future. Some other things such as designing a model to handle the arrival flow of EVs at battery charging/exchanging station, number of stations that will be sufficient in an area to handle all the EVs are other areas of future work. Moreover, trip and tour can also be evaluated using additional datasets, critical control parameters could also be analyzed. As well as, the implementation of the proposed approach on real PHEVs is could be one of the interesting future research topics.

Bibliography

- [1] A. Ipakchi and F. Albuyeh, “Grid of the future,” *IEEE Power and Energy Magazine*, vol. 7, no. 2, pp. 52–62, March 2009.
- [2] X. Yuan, Z. Qian, Y. Zhou, Y. Wang, and M. Yan, “Discussion on the development trend of smart grid and its key technology,” in *Electricity Distribution (CICED), 2012 China International Conference on*, Sept 2012, pp. 1–8.
- [3] “Smart grids-ieee,” [Access: 2016- 05-10]. [Online]. Available: [texttthttps://www.ieee.org/about/technologies/emerging/emerging_tech_smart_grids.pdf](https://www.ieee.org/about/technologies/emerging/emerging_tech_smart_grids.pdf)
- [4] C. Macharis, P. Lebeau, J. V. Mierlo, and K. Lebeau, “Electric versus conventional vehicles for logistics: A total cost of ownership,” in *Electric Vehicle Symposium and Exhibition (EVS27), 2013 World*, Nov 2013, pp. 1–10.
- [5] Y. Zheng, Z. Y. Dong, Y. Xu, K. Meng, J. H. Zhao, and J. Qiu, “Electric vehicle battery charging/swap stations in distribution systems: Comparison study and optimal planning,” *IEEE Transactions on Power Systems*, vol. 29, no. 1, pp. 221–229, Jan 2014.
- [6] H. Yang, C. Y. Chung, and J. Zhao, “Application of plug-in electric vehicles to frequency regulation based on distributed signal acquisition via limited communication,” *IEEE Transactions on Power Systems*, vol. 28, no. 2, pp. 1017–1026, May 2013.

- [7] L. Schipper, L. Scholl, and L. Price, "Energy use and carbon emissions from freight in 10 industrialized countries: An analysis of trends from 1973 to 1992," *Transportation Research Part D: Transport and Environment*, vol. 2, no. 1, pp. 57 – 76, 1997. [Online]. Available: <http://www.sciencedirect.com/science/article/pii/S1361920996000144>
- [8] "Performance characteristics of byd e6." http://en.wikipedia.org/wiki/BYD_e6, Dec 2014.
- [9] W. Su, H. Eichi, W. Zeng, and M. Y. Chow, "A survey on the electrification of transportation in a smart grid environment," *IEEE Transactions on Industrial Informatics*, vol. 8, no. 1, pp. 1–10, Feb 2012.
- [10] "State grid corporation of china planning to vote for 20\$ billion to build electric vehicle charging facilities," Dec 2011. [Online]. Available: <http://feature.mei.net.cn/charging/news/20111231/407643.htm>
- [11] G. Wu, K. Boriboonsomsin, and M. J. Barth, "Development and evaluation of an intelligent energy-management strategy for plug-in hybrid electric vehicles," *IEEE Transactions on Intelligent Transportation Systems*, vol. 15, no. 3, pp. 1091–1100, June 2014.
- [12] Q. Gong, Y. Li, and Z. Peng, "Power management of plug-in hybrid electric vehicles using neural network based trip modeling," in *2009 American Control Conference*, June 2009, pp. 4601–4606.
- [13] Q. Gong, Y. Li, and Z. R. Peng, "Trip-based optimal power management of plug-in hybrid electric vehicles," *IEEE Transactions on Vehicular Technology*, vol. 57, no. 6, pp. 3393–3401, Nov 2008.
- [14] M. Erol-Kantarci and H. T. Mouftah, "Management of PHEV batteries in the smart grid: Towards a cyber-physical power infrastructure" *2011 7th International Wireless Communications and Mobile Computing Conference*, July 2011 pp. 795-800

- [15] M. de Freige, G. Joos, and M. Dubois, “Energy management and scheduling in a fast charging station for phev batteries,” in *2011 IEEE Power and Energy Society General Meeting*, July 2011, pp. 1–5.
- [16] S. Bashash and H. K. Fathy, “Cost-optimal charging of plug-in hybrid electric vehicles under time-varying electricity price signals,” *IEEE Transactions on Intelligent Transportation Systems*, vol. 15, no. 5, pp. 1958–1968, Oct 2014.
- [17] C. Jin and X. Sheng and P. Ghosh, “Optimized Electric Vehicle Charging With Intermittent Renewable Energy Sources,” *IEEE Journal of Selected Topics in Signal Processing*, vol. 8, no. 6, pp. 1063-1072, Dec 2014.
- [18] “The truck dispatching problem,” *Management Science*, vol. 6, no. 1, pp. 80–91, 1959.
- [19] Y. Marinakis, M. Marinaki, and G. Dounias, “A hybrid particle swarm optimization algorithm for the vehicle routing problem,” *Engineering Applications of Artificial Intelligence*, vol. 23, no. 4, pp. 463 – 472, 2010. [Online]. Available: <http://www.sciencedirect.com/science/article/pii/S0952197610000606>
- [20] Zhang Qinghua and Liu Yao and Cheng Guoquan and Wang Zhuan and Hu Haiqin and Liu Kui, “Improved genetic algorithm for variable fleet Vehicle Routing Problem with Soft Time Window,” *2008 6th IEEE International Conference on Industrial Informatics*, July 2008 pp. 233-238
- [21] C. Prins, “A simple and effective evolutionary algorithm for the vehicle routing problem,” *Computers & Operations Research*, vol. 31, no. 12, pp. 1985 – 2002, 2004. [Online]. Available: <http://www.sciencedirect.com/science/article/pii/S0305054803001588>
- [22] S. Erdoan and E. Miller-Hooks, “A green vehicle routing problem,” *Transportation Research Part E: Logistics and Transportation Review*, vol. 48, no. 1, pp. 100

- 114, 2012, select Papers from the 19th International Symposium on Transportation and Traffic Theory. [Online]. Available: <http://www.sciencedirect.com/science/article/pii/S1366554511001062>
- [23] J. Lin, W. Zhou, and O. Wolfson, “Electric vehicle routing problem,” *Transportation Research Procedia*, vol. 12, pp. 508 – 521, 2016, tenth International Conference on City Logistics 17-19 June 2015, Tenerife, Spain. [Online]. Available: <http://www.sciencedirect.com/science/article/pii/S2352146516000089>
- [24] H. G. Chale-Gongora, O. de Weck, A. Doufene, T. Ishimatsu, and D. Krob, “Planning an itinerary for an electric vehicle,” in *Energy Conference (ENERGY-CON), 2014 IEEE International*, May 2014, pp. 1385–1391.
- [25] C. Bingham and C. Walsh and S. Carroll, “Impact of driving characteristics on electric vehicle energy consumption and range,” *IEEE Transactions on Intelligent Transportation Systems*, vol. 6, no. 1, pp. 29-35, march 2013.
- [26] M. Neaimeh and G. A. Hill and Y. Hbner and P. T. Blythe, “Routing systems to extend the driving range of electric vehicles,” *IEEE Transactions on Intelligent Transportation Systems*, vol. 7, no. 3, pp. 327–336, September 2013.
- [27] “carstations,” <http://www.carstations.com>.
- [28] “chargemap.com,” <http://chargemap.com/>.
- [29] J. Heywood, P. Baptista, I. Berry, K. Bhatt, L. Cheah, F. Sisternes, V. Karplus, D. Keith, M. Khusid, D. MacKenzie and J. McAulay, “An Action Plan for Cars: The Policies Needed to Reduce U.S. Petroleum Consumption and Greenhouse Gas Emissions,” *MIT Energy Initiative, Cambridge, Massachusetts*, Dec 2009

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url “<https://www.youtube.com/watch?v=nMdm0mCp3-A>”