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Geolocation based Addressing system using GPS Coordinates for Smart Cities

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ABSTRACT
In this Study a new House or Property addressing system is proposed for the Smart Cities. The basic idea behind this study is to use GPS coordinates of a particular location and convert them into short alphanumeric string and assign them to House address or Property Id for Smart Cities. The use of GPS coordinates ensures the location of particular address with reference to the ground. The address is referred as 3D Address due to involvement of height from GPS coordinates and therefore can locate the floor number in case of multi-storeyed building. The outcome unique address can be digitally used to integrate various services and departments where location or address is involved. The Proposed system is not only beneficial for Authorities but also for the citizens.

Keywords: Geolocation, Geocoded Address, 3d Virtual Address, GPS Coordinates, Smart Solutions, Unique Property Id, Smart City Mission

INTRODUCTION

Now a day location has involved in may web applications. In daily life people uses navigation services in their mobile devices. This has become possible due to the easy availability of Satellite, Geographical Information system (GIS) and Global Positioning System (GPS) technology. Almost all smart phone comes with inbuilt GPS feature. Advancement in hardware and software resulted in the new web services development. The GPS technology has a great impact upon the lifestyle of peoples. Taxi service, parcel delivery, e-commerce are some examples where this technology is now being extensively used. The Smart City mission has the similar objective to increase the quality of life of its citizens by providing core infrastructure and a clean & sustainable environment. There is no standard definition available for a Smart City and itis different things to different people. The conceptof Smart Cityvaries from city to city and country to country and depend upon the various local factors including the citizens.The Smart Citiesmission in India is launched by Ministry of Housing & Urban Affairs, Govt. Of India. Cities are the major contributor in economic growth of every country. Approximately 31% population of India lives in urban areas and have 63 % contributionin national GDP (Census 2011).It is expected that by the year 2030 40% of total population will live in urban areas and will contribute 75% in national GDP(Ministry of Urban Development, GOI, 2015).It is necessary to comprehensively develop the physical,institutional, social and economic infrastructure. The Smart Cities mission is a step in improving the life standard of citizens and also to attract people and investments in the City for growth and development. The Smart Cities Mission expects smart people who can actively participate in governance and reforms. The mission also targets to the maximum participation of smart people through development and use of Information and Communication Technology especially mobile-based tools for the smart solution. The mission mainly focusses for the smart solution E-Governance and Citizen services, Waste management, water management, Energy management, urban mobility. The list is however not exhaustive and cities are free to add more applications. The SmartSolutions can be implemented by using technology, information and data in the improvement of infrastructureand services resultingto the improved quality of life,employment opportunities and of course enhancement in incomes.If list of smart solution is observed, thenit is clear that location information is very important and invites the use of GIS and GPS based technology. The

Administrative Reforms Commission recommended that GIS technology should be used for property tax mapping. The GIS maps helped in improving the coverage (Rao, 2013). As a part of the Smart solution, the authorities of Smart Cities may need to be integrate the services between different departments. The Authorities may also need to interact with citizens by offering them various services. For any Smart City house addressing is an important as well as a challenging thing. Address locating is a global problem and in most parts of the world, buildings and housed do not have proper street addresses and in some cases if address is available it cannot be reached without local knowledge(Rinckes & Bunge, 2019).It is some time difficult to find the location based on postal address, House number, street number etc. Most of the area does either do not have proper numbering system or the same house number may be repetitive. The problem is not only faced by citizens but also by the Government authorities especially in case of legal correspondence, Municipalities for property tax collections or general navigation to address. To solve this problem a proper addressing system is required which can uniquely identify a particular location. This problem encourages to develop a Geolocation based addressing system for the Smart city by using ICT, GIS and GPS technology. Similar to the objective of Smart city mission, this solution shall be replicated and used outside of Smart city Area.

Geolocation and The Coordinate System

A geolocation is the real-world geographic location of an object on earth in the form ofGeographic coordinates. The Geographic coordinates are generally represented by numbers, letters and symbols. The earth is divided into imaginary vertical and horizontal lines called Longitude and Latitude. The Longitude ranges from 0 degree at equator to 90 degrees of both North and South pole. The Horizontal division ranges from 0 degree at Greenwich to 180 degrees East and West. The Geographic coordinates is a referencing system to represent the location of an object and can be provided through GPS. There are two types of coordinate systems commonly used in GIS(ESRI, p. 2019). The first is the Spherical or Global coordinate system such as longitude and latitude. These are commonly known as geographic coordinate systems. The second is the Projected coordinate system which definemethods to project three-dimensional surface to two-dimensional plane. This is applied tomap the 3D spherical surface of earth onto a two-dimensional plane. These are also referred as map projections.

Global Positioning System (GPS)

The Global positioning System (GPS) is owned by U.S. Government. It provides position, navigation and timing (PNT) services (U.S. Government, 2019). The entire system is divided into three segments: Space, Control and User segment. The space and the control segment are developed, controlled and maintained by U.S. Air Force. The space segment has constellation of 24 satellites transmitting current satellite position and time to user through radio frequency. The 24 operational GPS satellite are committed to be operational 95% time by U.S. Government. The control segment has control and monitoring stations worldwide and tracks the satellite status, health and uploads navigation data. In the user segment GPS receiver receives the signal from GPS satellite and calculates the user's position in three-dimensional space and provides the Latitude, Longitude and Altitude.

National Map Policy

Different Countries may follow their Map policies and may use different coordinate systems. In India, Survey of India has the responsibility for producing and maintaining the topographic map database(India G. O., 2005). According to the national map policy the datum World Geodetic System (WGS 84) and Universal Transverse Mercator (UTM) projection shall be used.The Universal Transverse Mercator (UTM) is a grid system in the Transvers Mercator projection 6^0 wide zones as defined by (Hager, W., Fry, Jacks, & Hill, 1990) in the technical manual. Similar to the traditional method of latitude and longitude, it is a horizontal position representation, and used to identify vertical position locations on the Earth. The UTM system divides the Earth into sixty zones, each being a six-degree band of longitude, and uses a local projection in each zone.

EXISTING SYSTEMS

In simple words we can say geolocation involves the generation of a set of geographic coordinates such as Latitude-Longitude. But it is not a good approach to directly use these long numerical values of UTM coordinates as an address.The goal is touse these coordinates are used to determine a meaningful location, such as an address in more realistic way.In this direction some organizations such as Google, What3Words, Mapcode Foundationare already working in making the coordinates usable as an address.

World Georeferencing System (GEOREF)

The World Geographic Reference System is an areadesignation and position reporting method(National Geospatial-Intelligence Agency, 2014).It is mainly used by Air defense and strategic air operations in internal service. It is a method to report and plot the position in a form suitable for any map or labelled with latitude and longitude. GEOREF outputs a geographic area in which a specific point is located. In this system the Earth is divided into a grid of longitude and latitude. A systematic code is provided for the location identification in each

grid. There are 24 zones of Longitude and 12 zones of Latitude. Each zone is separated by 15 degrees. The Longitude vertically extends 180° starting from meridian towards east. The Longitude zones are represented by letters from A to Z and the letters "I" and "O" are omitted. Similarly, the 12 bands of Latitude separated horizontally of 15 degrees, extends from the South Pole towards North Pole. The Latitude bands are represented by letters A to M and only one letter "I" is omitted. At first level this method divides the earth's surface into 288 quadrangles. The coordinates values are represented by two letters. The first letter represents Longitude and the second letter represents the Latitude. Further levels of subdivision are carried out with letters and numbers. This system can locate a position of 0.1 minute with four letters and six numbers and can locate 0.01 minute with four letters and eight numbers.

Open Location Code or Plus code

Doug Rinckes, Philipp Bunge from Google proposed a standard for communicating location information from person to person or between person and computer.The Open Location Code (OLC) is also referred as Plus code was developed by Google and released in the year 2014. It is a geocode system for identifying a location on the Earth. These are also known as plus codes. These Codes are a technique of encoding location into aneasily readable and usable forminstead of latitude and longitude. To shorten the latitude and longitude the OLC system uses a base 20 number system to represent 14x14 meter area by 10 digits. The 20-character set "23456789CFGHJMPQRVWX"is derived from 0-9 numbers and A-Z alphabets. OLC encodes WGS84 in degrees and the decoding outputs an area. The Plus code may of variable length depending upon the amount of precision value of location. As long as the code, the smaller the area it represents. A two-digit code represents area of 20 degrees height and width. Further digits can be added in pairs and each pair will dived the height and width by factor of 20. Similar to GEOREF, Plus code uses grid-based subdivision and digits are added level by level. The area represented by 10-digit code is divided by the grid size of 4x5 and each cell is represented by a single digit. This refinement step enables 11-digit code to represent 3.4m x 2.7m area at global level. Further level of code shortening is also applied by Plus code. In order to make the code shorter in local perspective the common name of a larger area such as the name of Country, State is omitted and a shorter but local address is obtained. In representation of plus codes, a "+" symbol is noticed which is placed after the eighth digit global code of a location. The Plus Codeswere primarily designed for the internal use by Google itself in their mapping and navigation services but now these are freely available.

What3Words

The What3Words developed by Manchester Geomatic ltd.is also a location based addressing system. (Barr, 2015)defines the What3Words system in the technical appraisal.It is a geocoding system for representing the locations with a resolution of three meters.It can be easily understanding by resembling it with Internet Protocol (IPv4) address system of a computer network where four groups of numeric digits are formed and separated by a dot "." symbol. The What3Words system can represent the address in three numbers between 1 and 40,000. Although this is smaller than Latitude and longitude values but also difficult for humans to remember this digital sequence of numbers. The What3Words method replaces the numbers by three dictionary words. The words are derived from a custom dictionary containing 40,000 words. For example, the address of Manchester university can be written as "wishes.ripe.crust"by this technique.TheWhat3Words system follows a Grid referencing technique anddivides the ground in 3-meter by 3-meter grid and assign it a three dictionary words separated by a dot. Unlike other location encoding systems, it displays three words rather than long strings of numbers or letters. It encodes and decodes the WGS84 latitude longitude of center of a square grid.Maximum separation of two adjacent what3words address can be 2.12 meter. The fine accuracy is dependent on the accuracy of GPS receiver.The intended purpose of this addressing method is for navigation and suitable to locate door level, entry of building or way point and not suitable for survey purpose. The two adjacent address have separate three words address and may not have any common part and do not have a sequence, therefore user may face difficulty in locating or searching the address of a particular property. The system uses a fixed algorithm; therefore, large database is not required to store every location on earth but a custom dictionary needs to be stored. This algorithm can work on small devices with limited storage. The API services are also available to integrate in the existing web services.

MapCode

Another public domain addressing system is Mapcode. This system is developed and maintained by The StichtingMapcode Foundation. It was developed by the company as freely available international standard for representing the location through numbers and letters. According to (Geelen, 2014)Mapcode it as a new standard for location encoding system that allows to represented a location by a short easily recognizable and memorable code.The structure of Mapcode is consist of two groups of letters and digits, separated by a dot. The length may vary from four characters to seven characters.The system converts latitude and longitude to mapcode

using 32-bitarithmetic system. It can convert 5-meter grid into four characters separated by a dot. The first letter divides the grid into 30 zones of 5x6 size, and then 6x5 size grid by the second letter. It represents a location within the context of a separately specified country or territory. The address of the Eiffel Tower in Paris according to this system is "France 4J.Q2" as an example given by the author. In the local prospective the name of country is omitted in the code which makes the code shorter. The map code algorithm converts WGS 84 coordinate into a map code, and vice versa.

Loc8Code

The Loc8Code was developed in Ireland by GPS Ireland Ltd and now managed by Loc8Code Ltd. The code consists of eight alphanumeric characters of numbers and letters and locate the position with accuracy of six meters (Loc8Code Ltd, n.d.). This is a geocoding system as it determines the position calculated from the latitude and Longitude through their own Loc8Code software. The characters in the code are grouped in three parts separated by a "- "symbol. In the structure of Loc8Code the first letter is always a letter and covers approx. 90 square Km area. The second two characters can be letter or a number and covers 3.5 square km area within the area of first character. By adding more characters, the coverage area narrows down. The code also has a provision for checksum error.

ORIGIN OF THE PROBLEM

The above-mentioned techniques are good but they have only Citizen centric approach and lacks with Government Authorities prospective. The present system aims to navigate the user within 3 to 5-meter radius of the destination address which is not again a pin point address to be used in administrative decision. Also,it is difficult to refer floor number where height or altitude requires to locate the particular floor in multi-story building or tower apartments. The Municipal Authorities are collecting property tax from the citizens. In the property tax system, a unique property identity number is assigned to each property holder. This Id is generally based on boundaries such as Area code, Sector number, Zone number, ward number, locality and then a sequential number in a street. By adding all these codes, the length of an IDs become up to 12 to 15 characters.It also becomes very challenging to generate new property ID when a property is further bifurcated or a new floor is constructed and leading to produce a new house address.The Administrative boundaries are also not fixed and they get changed from time to time according to administrative decisions. Due to involvement of boundaries in the property, the Ids requires to be changed accordingly and new Ids are assigned.Overall the pain goes with the citizens as they have to verify each year their property ID while paying the property tax. Lots of property tax bills remains undistributed due to improper and unreachable address. The typical address format in India comprises of house number, street number, sector number, locality name, City name, District and State Name. Sometime a local land mark is also specified in the address. The address does not strictly follow the same format for all places. There may not be street numbering available. The house numbers may be repeated or may be multiple house number for the same property referred in different documents. This situation is may be acceptable by citizens in their local area. But from the system point of view and for database designing it is a very complex problem and may be a resistance in application development. The smart solutions of the smart city are heavily dependent on the way of technological execution. By following a standard format and process the smart solutions can be replicated within Smart Cities as well as outside of Smart Cities. The house address is one of the major factors in smart solutions.

To solve all these problems a proper addressing system is required which can uniquely identify a particular location. It is proposed that it would be better if the addressing system is based on Geolocation. The existing Geolocation system in such as GPS coordinates in Latitude-Longitude form and are being used by GIS and in navigation system. But it does not seem meaningful to use them directly for addressing. For example, a particular location 29°07'27.8"N 75°42'18.2"E or 29.124381, 75.70505 consisting of 16 characters or can be of 20 characters for higher accuracy is very lengthy and difficult to remember and there are chances of error when communicating to someone through oral or through text massage. It should be shortened enough to be easily memorable by the citizens.

PROPOSED ADDRESSING SYSTEM

In this Study a new House or Property addressing system is proposed for the Smart Cities. The basic idea is behind this approach is to use GPS coordinates of the particular location and convert them into short alphanumeric string and assign them to House address or Property Id for Smart Cities. The use of GPS coordinates ensures the location of particular address with reference to the ground. The involvement of height from GPS coordinates enables us to locate the floor number in case of multistoried building. The proposed solution would be usable in generation a unique and unambiguous address of a particular location/House or

property to be referred by citizens or Smart City Authorities. The ownership of the particular asset may change but the geolocation address would remain the same. Also, it can also ensure the parcel delivery to the exact address. The objective of the study is to develop an addressing system based on Latitude, Longitude and Altitude and shortening the code to 5-6 digits which can be easily remembered by users. The proposed system uses both grid reference as well as character set encoding from custom base number system. Unlike above described system this system also included the height while encoding. The key features of the proposed system may be:

- Use of Latitude, Longitude and height for addressing.
- Use of Grid and character encoding based mixed approach.
- Uniquely Addressing below 2 Sqmeter land.
- Applicable within and outside of Smart City.
- Easy to implement and should support the mobile based web technology.
- Should support integration with other related web services through APIs.
- The system should work either in online or in offline mode.

This method will help in generating the address also in case of multi-story and multi-floor building. The proposed system is simple to implement andthe proposed algorithm can be designed with any commonly used programming language and can work in both online and offline mode. By developing the system APIs, it can be embedded or integrated with other services of the Authorities.

STUDY AREA

The Area of Interest (AOI) for the study is the State of Haryana situated between the coordinates 74oE, 31oN and 78o E 28o N shown in Figure 1. Total geographical area of Haryana is 44,212 Sq Km. Therefore, to generate the address within in 2 meter range the solution must incorporate at least 22,10,60,00,000 unique locations.

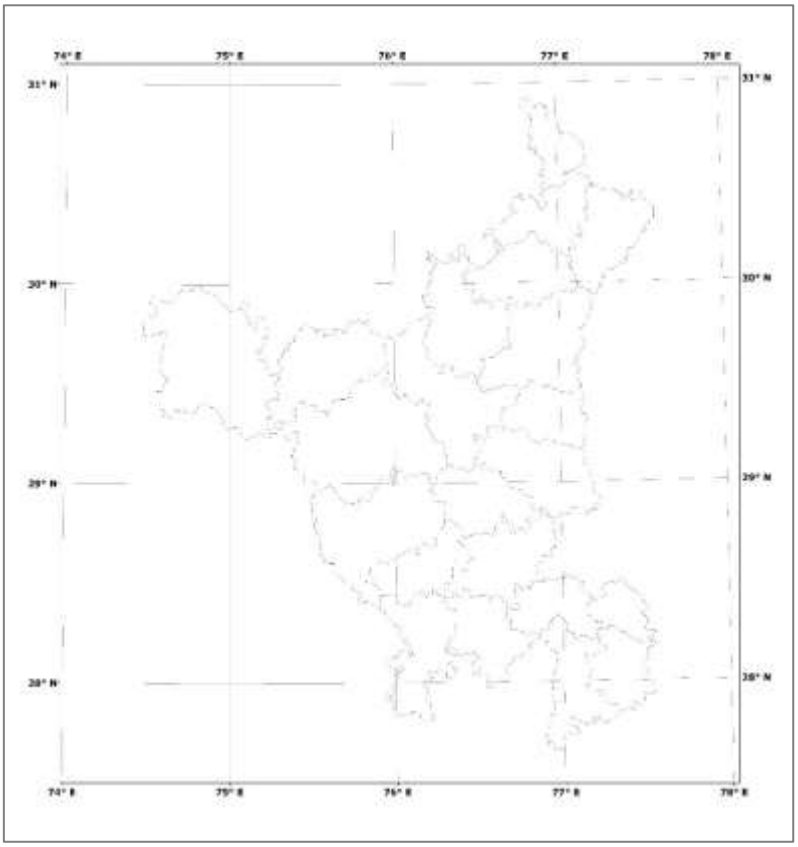

Figure 1Study Area- Haryana State

METHODOLOGY

To generate the proposed address, GPS coordinates values are required of the particular location. The GPS coordinates can be collected through a GPS device as well as thorough any smart phone having GPS facility. The GPS coordinates provides three location parameters- Latitude, Longitude for location and Altitude for the height. The proposed system follows a hybrid approach for encoding and decoding the values. The numeric values before and after decimal place are treated separately. The Degree value that is the values before decimal place changes very less on the city level and remains same for the city unless the boundary of the city is fall between two degrees' value. Therefore, it is better to follow a grid system on this level and represent the degree values that is the values before the decimal place in one character for approximate 100 Sq. km area. The numeric values after the decimal place is treated separately and encoded by the custom base 31 number table. All the three location parameters of GPS coordinates are parsed into a string. The String is then converted to Address code from the set of encoding characters shown in Table 1.After encoding through encoding algorithm, the geocoded address for the location is obtained. This geocoded address can be used as house address or a Unique Property Id. similarly through decoding algorithm the GPS coordinates can be retrieved back.The proposed methodologyis illustrated in Figure2.

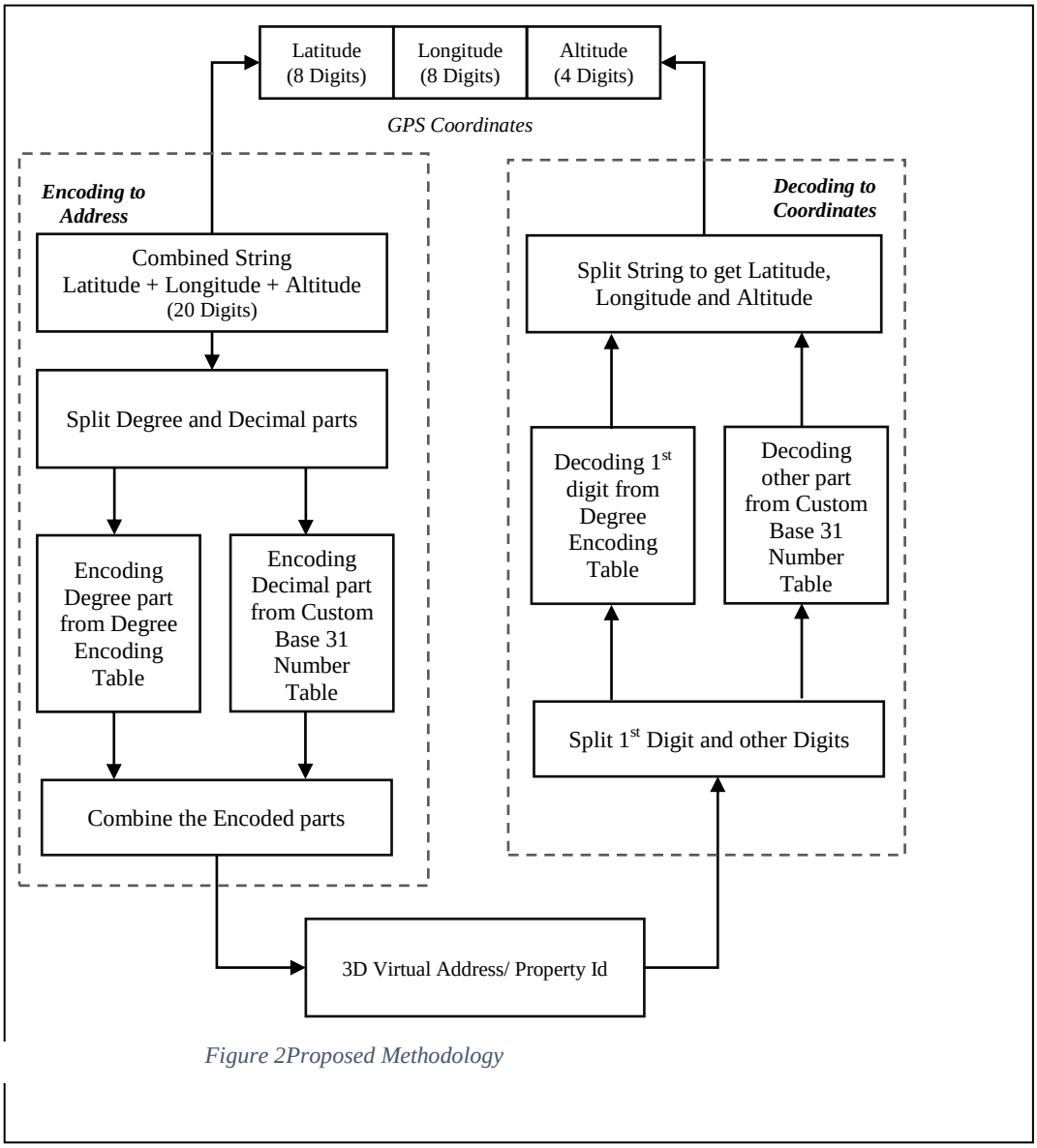

Figure 2Proposed Methodology

Character Set for Encoding

The proposed system usesa Grid based subdivision as well as encoding with custom Base Number System comprising of Numbers and Alphabets. The custom Base 31 number series is generatedfrom the different combination of numbers and Alphabets comprising of 31character set as shown in Table 1. Out of 26 English letters5 Alphabets are excluded to avoid ambiguity in reading letters or formation of offensive words as shown in Table 2.Table 3 shows the mapping of character for the degree values of Longitude and Latitude before the decimal place.

Table 1 Character Set used to generate base number

Numbers	0	1	2	3	4	5	6	7	8	9
Alphabets	B	C	D	F	G	H	J	K	M	N
	P	Q	R	S	T	U	V	W	X	Y
	Z									

Table 2Excluded Character Set

A	E	I	L	O

Table 3 Character Sets for encoding Degree values

	74^{O}	**75^{O}**	**76^{O}**	**77^{O}**
30^{O}	A	B	C	D
29^{O}	H	G	F	E
28^{O}	J	K	M	N
27^{O}	S	R	Q	P

In the first step the GPS coordinates of a location are taken as input. The coordinates values in 8 decimal places can provide location accuracy less than 2 meters. The encoding process is applied for converting the coordinates into 3d Virtual address. The encoding algorithm combines the Latitude, longitude and Altitude into a single string upto 20 characters. The strings are combined in such a way that degrees concatenated with degree, minute with minute and decimal value with decimal value of latitude and longitude.The Degree part i.e the values before the decimal place are encoded/decoded from table 3. The second part and altitude is encoded separately. Then values are matched in custom base table generated from the character set and the corresponding values are picked in group of three. The output is a string which represent the 3D virtual address of a location. The output string is much shorter than typical GPS coordinate values. Also this can be further shortened if we avoid the degree value because these values remain same approximately 100 by 100 km area. In order to obtain the GPS coordinate values from the virtual address a reverse process of decoding can be applied. In decoding process, the decimal values are obtained from the base table and then the string is split in three parts and latitude, longitude and altitude are obtained.

CONCLUSION

In this paper a Geolocation based addressing system has been proposed. The system is capable to convert the GPS coordinates to 8 to 9-digit address or vice versa. The 3D address itself contains the location information and unique for every location within 2-meter grid. The address can be assigned to each household or Property by the Smart City authorities or any Govt. authorities. By use of Mobile and GPS technology it will be easier to navigate to a particular address. This system also included the height to locate the floor number. The advantage of the proposed system is that it does not require any large database to store the address table. The address can be encoded or decoded with a simple computer program written in any computer programminglanguage and can be easily implemented. The proposed solution can be beneficial for Smart cities if implemented. The addresses are smaller and unique for each location and remains fixed once generated. Only one-time effort is required to collect the GPS coordinates to address the existing properties. It can be advantageous for both Government authorities as well as Citizens. Some major importance and usability are described as follows:

Importance for Government/Authorities

- **Unique identification of Property/Land***:* For Municipalities it is very important to implement property tax system. The property tax will get unique address for each location which will remove any ambiguity related to the address. The major problem arises when a property is bifurcated and required to generate a

new property Id. The Ids are typically based on administrative boundaries of Zone/Sector/Ward/Colony. These boundaries keep changes time to time due to administrative reasons. Then it is not possible to change the Property Id code and leads to confusion or duplicity in Ids. Also, sometime it is very difficult to manage property Ids in multi-floor building for example a shoppingmall. The Geolocation based Id can solve these problems.

- **Resolving Land Parcel Dispute:**A land parcel/Plot boundary can be freeze by the Geolocation based coding. Parcel Boundary related disputes may be reduced.
- **Better Revenue Generation:** The proposed addressing system can reduce the time and cost for planning and implementing the schemes/ progress work.
- **Security:**For the Security and monitoring authorities it is important to identify the crime spot, crime sensitive area, and the crime hot spot analysis.Navigation of fire brigade vehicle.
- **Healthcare Services:**Healthcare services can be reached well in time to rural as well as urban areas like Ambulance service.
- **Integration of Departments and Services:**To establish coordination between Government Departments it is necessary to integrate their services. The proposed address can be linked with the citizen Ids like Aadhar number, PAN number, Vehicle registration, Utility bills such as electricity, water supply bill and many more for better accounting.

Importance and usability for Citizens

- **Unique Address for each location:**The uniqueness of address has similar importance for the citizens as the govt.
- **Easy to remember and time saving:**The smaller code of 5-6 digits is easy to remembers by everyone.
- **Better Navigation and delivery of Goods on exact location:**By the navigation applications it would be easy to navigate and deliver the Goods and other courier service well in time.

Limitations

The proposed system can be very effective to use but it also has some limitations. The system is based on GPS coordinates and the availability of GPS coordinates is very important. To Generate the property Id or Address, it is necessary to collect the GPS coordinates of every house or property by the authority with proper care. The survey staff must ensure that at least 2-meter ground distance should be maintained between two consecutive locations while taking GPS reading. Authorities can also collect coordinates from crowd sourcing but this can be doubtful whether information is correct or not. Further the GPS devices are also having some limitation while receiving the GPS signals. In a covered area, high power electric field or in a very narrow street the chances of GPS error are more. The poor-quality GPS device itself have issue in collecting erroneous Coordinates and location accuracy is very important because incorrect location will result different address. The proposed addressing system is better suitable for navigation through computer or mobile devices but it is difficult to manually locate the address until citizens become familiar with the new system and may take some time for public acceptance.

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