

A Novel Method for Assisted- Indian Regional Navigation Satellite System

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ABSTRACT: Indian Regional Navigation Satellite System (IRNSS) is a system of satellites developed by India to become independent nation in the navigation technology. Upon receiving the navigation data bits using the radio signals transmitted by the satellites, a user computes its own location. For any user, minimum of four such satellites are required to compute its location. To decode fresh navigation data bits, a receiver requires at least 40 to 50 seconds in an area where the signal strength of satellites are high. But in a location like deep forest, urban canyons, inside a building, the signal strength is very poor. In such a situation, the receiver either takes too long to decode the messages or it may not receive the signal at all. The penetrated signal is enough to compute the distance from the satellite but is insufficient to decode the navigation messages. This results in long position computation time or a complete outage. In the emergency services such as SOS or 911 calls, a quick and accurate location is needed. For pre-programmed way point navigation, initial location is necessary prior to the travel. A novel method is proposed to compute the position using GSM or CDMA mobile network as assistance link. By exploring the Secure User Plane Location (SUPL) extension, the assistance parameters can be made available to the required users. This type for assistance is new to IRNSS receivers and is called as Assisted Indian Navigation Satellite System (A-IRNSS). Upon quickly receiving the live navigation bits, a user can obtain quick position within 3-4 seconds. Extensive experimentation has been conducted on real time satellite data.

KEYWORDS:IRNSS, SUPL extension, Assistance parameters, Satellite ephemeris, TTFF

I. INTRODUCTION

From the beginning of modern civilization, human beings used to think and use navigation in various ways in day-to-day life. People used geographical terrain, direction of wind, behaviour of animals, location of stars, maps and until last century the magnetic compass to navigate from one location to other. Mechanical devices such as gyroscopes, accelerometers are the results of industrial evolution in the last century. Radio beacons, radars are developed due to the invention of airplanes and rockets. In the 1980's a new system of satellites called Global Positioning System (GPS) were developed and using which the precise navigation was made possible globally in all weather conditions.

Indian Regional Navigation Satellite System (IRNSS) is a system of navigation satellites developed to compute the user position for any user. It is developed indigenously by Indian Space Research Organization (ISRO). The satellites are having two signals where in first, any civilian can obtain position solution to a course level and using the other, only military users can obtain position up to precise level. This navigation system is under complete control of Indian Government to be completely independent in navigation for both civilian and strategic applications. Until the

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development of this system, India was relying on American controlled Global Positioning System (GPS) or Russian controlled GLObal Navigation Satellite System (GLONASS) for both military and civilian applications. The IRNSS is currently planned to be regional to Asia – Pacific countries only.

In satellite navigation, all satellites are synchronized at a very high precision. Each satellite transmits the signals containing the data called ephemeris which can be used to compute the precise satellite position. By computing the signal transit time, any user on the earth surface can compute the distance from satellite. Knowing distance and locations of four such satellites, user can compute location by trilateration. The satellite position computed using ephemeris is highly precise whereas using almanac an approximate position can be obtained. The validity of ephemeris is only 2 hours and almanac can be used for longer duration up to few months. User location in the form of latitude, longitude and altitude can be computed using a small device called “receiver”. The device can be embedded into laptops or mobile phones.

IRNSS signal is transmitted in L5 and S bands with carrier frequencies of 1176.45 MHz and 2492.028 MHz respectively. The navigation data will be transmitted at a data rate of 50 symbols per second (sps). The signal structure having master frame contains four sub frames. Each sub frame is of size 600 symbols. The frames contain primary and secondary navigation parameters including ephemeris data, satellite clock and health information, almanac, text messages, orientation parameters for earth etc. [1]. The ephemeris parameters required to get the satellite position are available in the sub frames 1 and 2 as shown in the table 1.1.

Parameter Name	Symbol /value	Sub frame	Number of bits
Time of clock	t_{oc}	1	16
Mean motion difference	Δn	1	22
IODE	IODE	1	8
Amplitude of the Cosine Harmonic Correction Term to the Argument of Latitude	C_{uc}	1	15
Amplitude of the Sine Harmonic Correction Term to the Argument of Latitude	C_{us}	1	15
Amplitude of the Cosine Harmonic Correction Term to the Angle of Inclination	C_{ic}	1	15
Amplitude of the Sine Harmonic Correction Term to the Angle of Inclination	C_{is}	1	15
Amplitude of the Cosine Harmonic Correction Term to the Orbit Radius	C_{rc}	1	15
Amplitude of the Sine Harmonic Correction Term to the Orbit Radius	C_{rs}	1	15
Mean Anomaly	M_0	2	32
Time of ephemeris	t_{oe}	2	16
Eccentricity	E	2	32
Square root of semi-major axis	\sqrt{A}	2	32
Long of ascending node	Ω_0	2	32
Argument of perigee	Ω	2	32
Rate of RAAN	$\dot{\Omega}$	2	22

Table 1.1 Ephemeris parameters required for satellite position computation

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With the help of ephemeris parameters and standard user algorithm [1], it is possible to compute the satellite position at a given time. The satellite position is in the form of (X_i, Y_i, Z_i) for the i^{th} satellite. The distance from satellite to the user position (X, Y, Z) known as pseudo range will be obtained using the inbuilt receivers present in the user's mobile phones or lap tops. Thus, finally user position can be computed using Euclidean distance formula given in (1.1) [6]

$$\text{Pseudo Range } R = \sqrt{(X_i - X)^2 + (Y_i - Y)^2 + (Z_i - Z)^2} \quad \text{for the } i^{\text{th}} \text{ satellite.} \quad (1.1)$$

The user position computed is helpful in navigation applications and in emergency situations. The satellite signal should be available to get the position information. In situations where the satellite signal is weak, the ephemeris data bits are unable to decode and hence the position information will be inaccurate or position computation is not possible. To get accurate satellite position information in situations where signal strength is poor, a new concept of assistance is proposed. In GPS technology it is termed as Assisted - GPS or A-GPS. In the AGPS, GSM mobile base stations are used for getting satellite information through network signals. Similar new concept is proposed for IRNSS systems. Even though the satellite signals cannot penetrate into few areas, the GSM signal will be available at most places because of its frequency and signal strength.

II. RELATED WORK

Quick and accurate computation of user position in places where satellite signal strength is poor is achieved in GPS systems and known as Assisted - GPS [2]. For example in [2], the prediction data is collected from the Jet Propulsion Laboratory (JPL) server and requested mobile user is provided with the ephemeris data for position computation. In this approach, the assistance data is transmitted over Secure User Plane Location (SUPL) protocol [3]. Using the theory of perturbations and the mathematical prediction model, the satellite position for future days as well is predicted. It is common to store the previously collected satellite data in non-volatile memory such as EEPROM/Flash. Upon restarting the mobile phones or laptops, the receivers use previously stored ephemeris. Demerits of this approach are that the switch -off duration of the receiver is more than the validity time of previous ephemeris. It results in the inaccurate position computation. One can use almanac instead of ephemeris due to the longer validity of it, but with the help of almanac the satellite position accuracy is not enough to get the appropriate user position [2]. It can be explained graphically as shown in figure 2.1. The position computed using almanac results in more erroneous value compared to the value obtained using ephemeris. The difference from the true satellite path is less when position computed using ephemeris parameters. At time t_{oe} , there is no variation between true satellite position and computed values. t_{oe} is called as time of ephemeris.

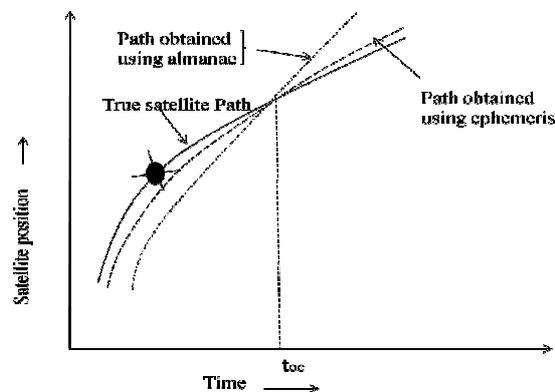


Figure 2.1 Satellite path variations due to almanac and ephemeris

The raw ephemeris collected from available live satellites can be transmitted using GSM network. Such methods are proposed and developed for GPS systems but no such assistance mechanism is developed for IRNSS so far.

III. ASSISTANCE MECHANISM

The proposed assistance methodology for IRNSS systems is as shown in the figure 3.1. In the system, there are mobile phones which are under base station coverage area which gets both IRNSS satellite signals and GSM/CDMA signals directly. Phones which are in the out of coverage area, gets only the satellite signals but not the network signals. Suppose a user phone is under deep attenuation for satellite signals, assistance parameters can be received from network base stations. One IRNSS receiver is placed in each such base station and this receiver will be under good signal condition for satellite signals. The satellite data received will be sent as assistance parameter for the mobile phones which are requesting for assistance under that base station coverage area.

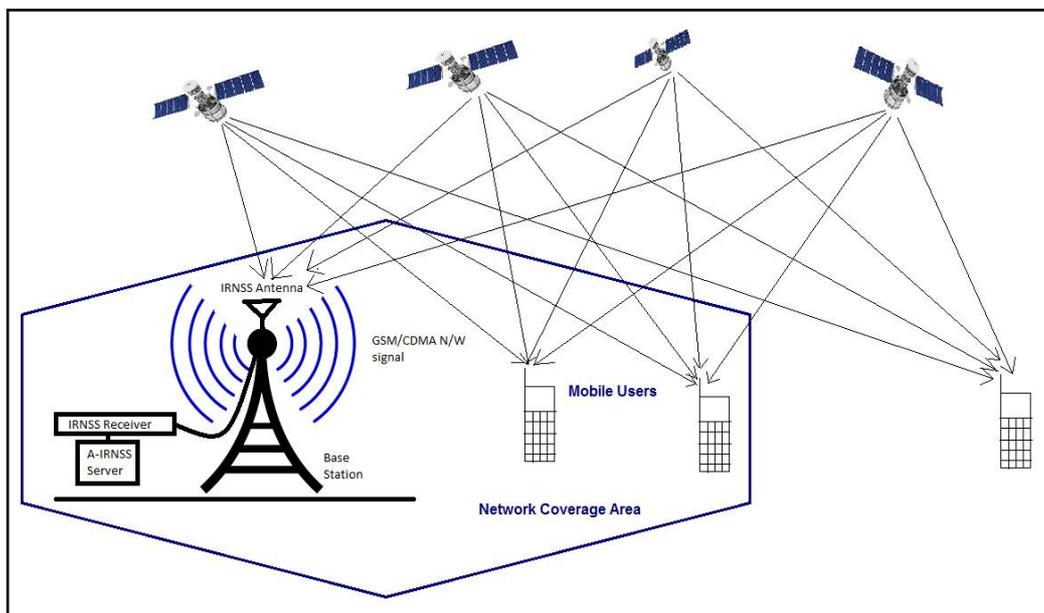


Figure 3.1 Proposed method for IRNSS Assistance mechanism

The satellite signal will be weak in places such as urban canyons, deep inside a forest or in parking lots underneath the building. In such places it is difficult to get user position accurately and it takes several minutes. The time taken to get user position first time when the mobile phone is switched on is called as ‘Time to First Fix’ (TTFF). TTFF [6] will be more for the phones which are out of network coverage because of the receivers needs to receive satellite-data directly from satellites. In the proposed system, A-IRNSS server having a receiver is kept in GSM base station which will have one IRNSS receiver and its antenna. The base stations will always be in the center of network coverage area and provide good GSM/CDMA signal to the mobile users. All base stations will have good visibility for the satellites and the same set of satellites is seen to the mobile users. The satellite data stored in the base station A-IRNSS server-database will be sent to the requested mobile user whenever necessary. Required parameters for position computations are extracted and compressed using effective compression algorithms to reduce the data size before sending to remotely located user. At receiving end, the assistance data is decompressed and position of satellite will be calculated using standard equations available as in [1]. The satellite data will be transmitted to the remotely located mobile user over the SUPL protocol via network. The process of system architecture is depicted in the figure 3.2. Lempel-Ziv-Welch (LZW) coding is a compression algorithm [7] used which compresses the data files to reduce size. Upon decompression, the original data is recovered without any loss. When this method is used to reduce the size of the assistance data it was observed up to 70% compression.

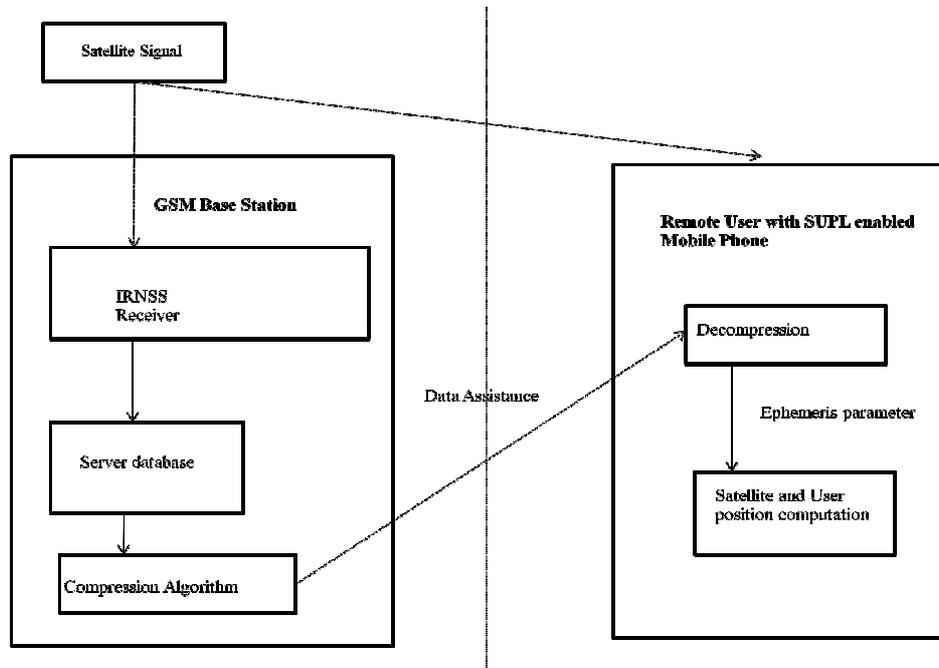


Figure 3.2 Architecture of proposed method

Advantages of the proposed method

1. Simple to implement: This method of assistance mechanism is simple as there is no complicated mathematical model involved. There is almost no change in the receiver satellite position computation. Instead of live satellite data it uses the assisted data through the GSM/CDMA link.
2. Accuracy: The position information obtained using assistance data is highly accurate due to the usage of raw ephemeris parameters in position computation. There is no degradation in any of the parameters of ephemeris data. Effectively this method is similar to the receivers collecting the data from live satellites.
3. Network Bandwidth/storage: The compression algorithms used will reduce the data size drastically. Hence the bandwidth used for transferring data from server base station database to the mobile user reduces.

IV. SIMULATION & RESULTS

Experimental simulations have been conducted to know the behaviour of validity of satellite parameters like ephemeris and almanac. Real-time ephemeris and almanac parameters were collected using an IRNSS receiver kept in a good visibility location over a period of 1 week. The satellite position using both ephemeris and almanac are computed using the equations in [1] with MATLABTM. The plots of vertical and horizontal position-error obtained using these two Keplerian parameters are shown in the Figure 4.1. It is observed that the position-error using almanac parameter is about 4000 meters from the real time satellite position over 7 days. The ephemeris changes every 2hrs and is more accurate to real-time position of the satellite. Hence to get accurate position values, ephemeris parameters have been used instead of almanac.

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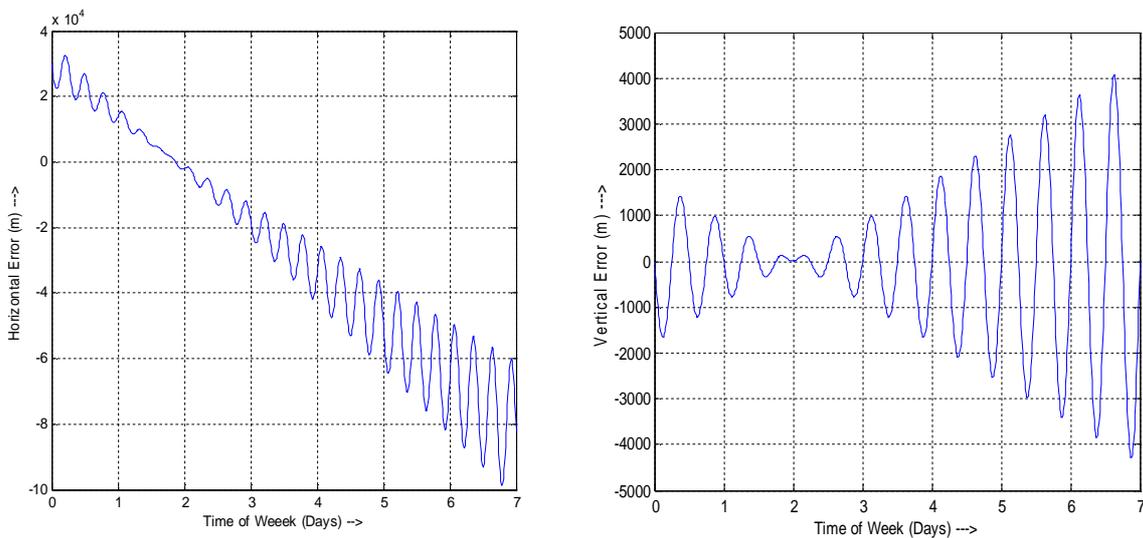


Figure 4.1 Vertical and horizontal position - error between almanac and ephemeris parameters

The proposed scheme is demonstrated in real time with the help of two computers. One computer system acts as a server located in a GSM base-station. The system is located where the satellite signal strength is good and it collects the real time satellite data using one IRNSS receiver. The other computer acts as a client machine, which is a mobile-user in real scenario, which in the need for the assistance data as it is in a remote place. The real time data collected from the IRNSS receiver is kept in a database and processed according to the proposed scheme. The parameters required to compute position is extracted and compressed using LZW coding mechanism implemented in Java codes. The compressed parameters are sent to the client machine via client-server programming for the lab demonstration. At the client machine end, the obtained parameters are decompressed and the position of satellite at a given time is computed. The real time simulations and experiments carried-out using Java and MATLAB™ were conclusive to deploy this scheme into mobile base-station. The set-up of lab demonstration of the proposed concept is depicted in Figure 4.2.

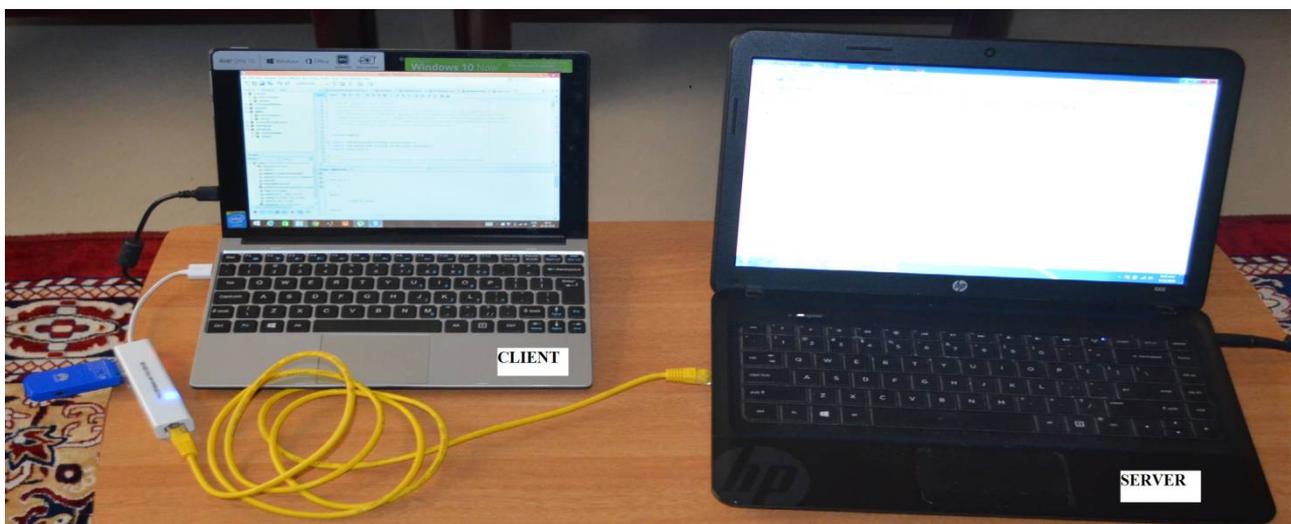


Figure 4.2 Lab demonstrations of IRNSS Assistance mechanisms

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V. CONCLUSION

With the help of data assistance using GSM base stations, it is found that the position for a user can be obtained accurately within few seconds even though the user is located in remote area where the satellite signal strength is poor. The method can be implemented in real time by getting the real time data and compressing it and sending it to the other system where the position computation is carried out. The position information computed using the assistance method is valid for the duration of ephemeris validity only. Since each base station requires a receiver, the numbers of base station receivers are more. The total number of receivers can be reduced by performing a study on the area of coverage and the satellite visibility in the coverage area. Each set of ephemeris is valid only up to 2hrs, which is the ephemeris validity duration, so the number of assistance traffic up to a week becomes more. It needs $7(\text{Number of satellites}) * 12$ (transmissions in a day)*300 bits (Ephemeris bits)*7days = 176Kbit.

The assistance is not possible for the user which is out of coverage area. This method needed continuous network signals. Using the history of satellite data, position information for future days can be predicted and sent as assistance data to overcome this drawback.

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