Chapter 2
Spatial-Positioning Technology

Introduction

Spatial-positioning technologies are technologies that supply location or position information, applications, and services related to specific users while using the Global Positioning System (GPS). It gives operators an opportunity to precisely find a location, and as a result it enhances revenues, provides new services, and meet general public safety demands. For example, the available services support end user through different means including the support for emergency response using emergency call-up devices as well as support for customers in finding the best products at price tags identified in location-aware systems for vehicle routing, tracking, location finding, and business transactions.

The Global Positioning System (GPS)

The NAVSTAR GPS is a satellite-based positioning and timing system designed, supported, deployed, managed, and operated by the United States (US) Department of Defense (DoD). GPS has shown a substantial benefit for the civilian communities that are applying GPS with a rapidly expanding quantity of applications. What attracts to GPS particularly is the following:

- It has comparatively high positioning accuracies from tens of meters right down to centimeter level.
- It provides ease of determining velocity and time to a relative accuracy corresponding to the position.
- The signals are offered to customers anywhere on the globe: in the air, on land, or at sea.

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- It is a positioning system with no user fees that simply requires the use of relatively low-cost GPS receiver.
- It is an all-weather system available 24/7.
- The position information is given in three proportions, i.e. both vertical and horizontal information is furnished.

System Components

The GPS system comprises three fragments: (a) the space segment, which comprises the particular satellites as well as the transmitted signals; (b) the control segment, i.e., the ground facilities execute the processes of satellite tracking, orbit calculations, telemetry, and supervision needed for proper control on the space segment; and (c) the user segment, which is the whole spectrum regarding application products and computational process that can be found by certain users.

Space Segment

GPS consists of a constellation of 30 active and spare satellites owned and operated by the US DoD, and 24 of these satellites represent the active space segment. The orbit altitude is as follows: The satellites repeat an identical track as well as configuration over any place approximately each day (24 h) (4 min earlier just about every day). The space segment comprises six orbital planes with nominally 4 satellites for every plane as shown in Fig. 2.1. The constellation affords the user

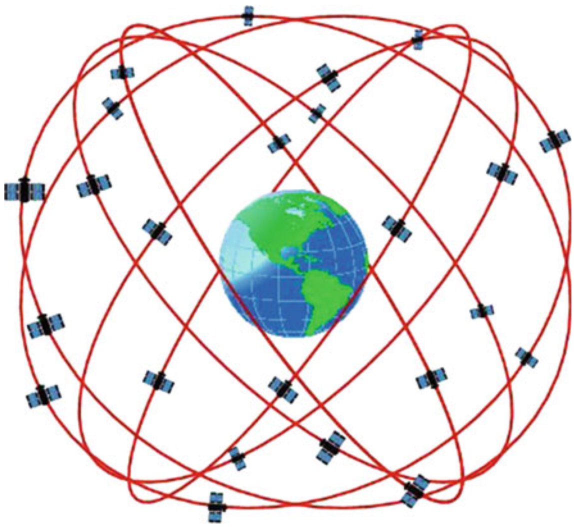

Fig. 2.1 GPS nominal constellation

together with between five to nine eight visible satellites from virtually any point around the Earth. These satellites contain an atomic time clock, a computer, and a radio to continuously analyze and transmit the satellite's position. On the ground, GPS receivers process signals from satellites on the horizon and calculate their position, time and velocity (at least for 4 satellites) by applying triangulation. As a result, these calculations can offer a three-dimensional position: latitude, longitude, altitude, and time.

The Control Segment

This control segment comprises all facilities necessary for satellite-health monitoring, telemetry, pursuing, command and control, satellite orbit and clock-data computations, and data up-linking. There are five ground facility areas—Hawaii, Colorado Springs, Ascension Island, Diego Garcia, and Kwajalein—as shown in Fig. 2.2. All are owned and operated by the US DoD and perform the following functions:

- All five stations are monitor stations equipped with GPS receivers to track the satellites. The resultant tracking data is transferred to the master control station.
- Colorado Springs is the master control station (MCS) processes the tracking data to compute the satellites' ephemerides (orbital information) and determine satellite clock corrections. In addition, it is the place that initiates all operations on the space segment such as spacecraft maneuvering, signal encryption, and satellite clock-keeping.

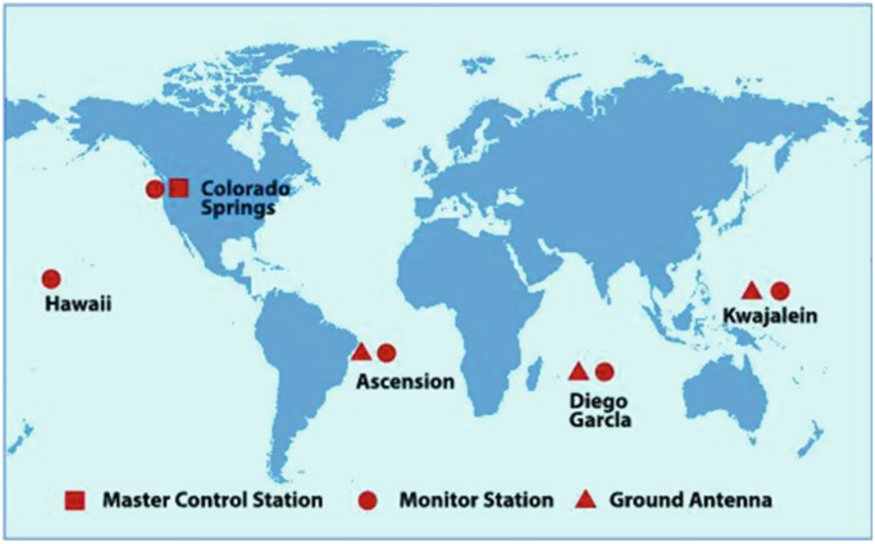

Fig. 2.2 Control segment of GPS

- Three of the stations (Ascension Island, Diego Garcia, and Kwajalein) are upload stations enabling the up-link associated with data on the satellites. Data include the orbit and clock-modification information transmitted in the navigation message as well as command telemetry from the MCS.

A system of station tracking is located worldwide to transform the incorporated fed signals from the satellites into orbital designs. These models compute precise orbital data-clock corrections for every satellite. The Master Control Facility in Colorado Springs, US, uploads this particular data periodically to or any all satellites.

The User Segment

The user segment includes the tools of the current military personnel and civilians that receive GPS signals. The integration connected with military GPS-user products for fighters, bombers, tankers, helicopters, boats, submarines, tanks, jeeps, and soldiers' products. In addition to basic navigation activities, military GPS programs include targeted designation, near air assist, "smart" weapons, and rendezvous.

The civilian population has its very own large and diverse user segment. Surveyors employ GPS to save time compared with standard survey techniques. GPS can be used by planes and boats for en-route navigation and for airport or harbor solutions. GPS monitoring systems are employed to route and keep track of delivery and emergency vehicles as well as many other types of accurate-application vehicle tracking. Precision farming is an advanced method where GPS can be used to supervise and control the use of agricultural fertilizer and pesticides. GPS is now available as an in-car navaid, and many hikers and hunters use it. Because the actual GPS user does not have to communicate with the satellite, GPS can easily serve an unlimited number of users.

GPS Positioning Principles

The basic concept of GPS positioning is that of positioning-by-ranges as shown in Fig. 2.3. In the two-dimensional situation, a calculated range with a known level constrains the positioning to lie inside a circle while using the measured range as the radius. In three dimensions, any limited range with a known level constrains the positioning in a 3-D place to lie on the outside of any sphere centered at the common point with the particular radius becoming the calculated distance. With GPS, the distance measurement is made by a satellite with an identified position. The satellite ephemeris data transmitted by the navigation massage are employed to provide satellite coordinates. Nonetheless, the principle applies to any range-measuring positioning system whether terrestrial or satellite-based.

Throughout a two-dimensional system, the position can be explained as the intersection involving distances $d1$ and also $d2$ to two identified points as shown in

Fig. 2.3 Surfaces of position for range measurements

Fig. 2.4. It is imperative to realize that there are two possible solutions, only one of which can be correct. Generally speaking, one solution might be discarded quite easily by way of a priori expertise in approximate position and velocity. Another possibility is to always measure a different range to a third point, and with no error measured in any of the three points, the intersection involving three circles is usually a single exclusively defined point.

In the three-dimensional situation, the intersection of three spheres explains two points in space, only one of which is correct as shown in Fig. 2.5.

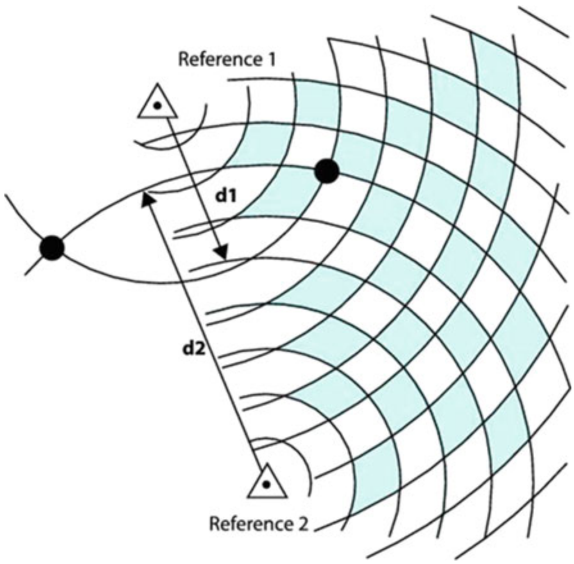

Fig. 2.4 The circular lines of position for 2-D positioning

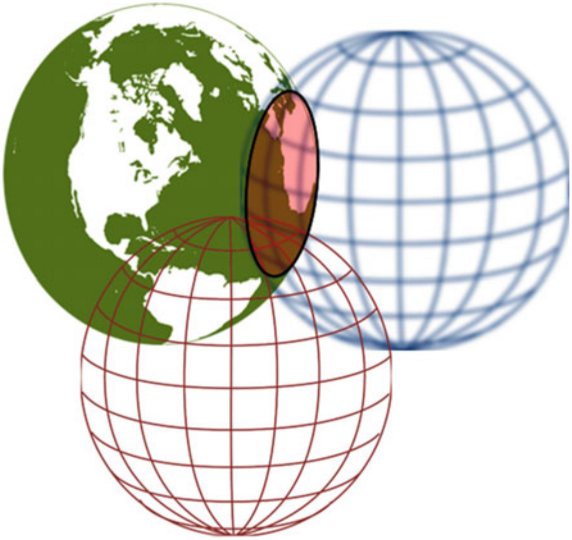

Fig. 2.5 Intersection of surfaces based on range measurements

Therefore, a minimum of three ranges are necessary, to three separate common points, to solve the 3-D position problem. The quality of the positioning solution relies, amongst other pursuits, on the remarkable accuracy with that the ranges offer in terms of measured accuracy along with the geometry of the intersection.

A fourth satellite is necessary because GPS uses constant measuring of distance, which causes the receiver's clock not to synchronize while using the satellites clocks. That is the reason why signals from a minimum of four satellites are required.

Sources of Errors

The sources of errors of the GPS are as follows:

(1) Selective availability (SA): This is an artificial error introduced from the satellites' signals from a security approach. The dimension of the error is approximately 30 m. The SA was turned off in 2001.
(2) Ionosphere delay: Physical conditions from the ionosphere, which are dependent on the number of electrons, can lead to errors in the measurements. The dimension of the error is approximately 20–30 m throughout the day and 2–6 m during the night.
(3) Troposphere delay: This occurs in the lower part of the atmosphere. The delay can be as high as 30 m for satellites close to the horizon; however, the error is practically constant and easy to model.

(4) Satellite orbit error: This is the difference between the actual positions of the satellite along with the position calculated from the emitted orbit data. The error is normally <3 m.
(5) Multipath error: This is a barrage involving signals coming to the receiver, primarily from the immediate one and then some from delayed reflected ones. This creates a new disordered signal. If the bounced signals are strong enough, they might confuse the receiver as well as cause erroneous measurements.

Accuracy of GPS

One of the benefits of the GPS as a necessary feature involving operation is how the carrier, as well as the data-modulating frequencies, are usually held to precise tolerances. That is true despite some restrictions involving the carrier and codes.

The GPS system delivers two services: Precise Positioning Services (PPS) according to P-code and Standard Positioning Service (SPS) with the shutdown of Selective Availability (SA) the accuracy is 10 to 15 meters, according to C/A code. The SPC accuracy will be at about few meters. This service is only available for authorized users with cryptographic equipment and keys. Before March 2000, only the U.S. and allied military, specific U.S. Government departments, and selected civil users specifically approved by the U.S. Government may use PPS. As of March 2000, all users may use PPS.

According to mobile cellular phone integrated with a GPS receiver, the location approach is useful and beneficial. Good GPS precision is achievable by minimum requirements in open areas. The disadvantage may be the attenuation involving satellite signals by buildings and urban infrastructures. As a result, reception of an adequate amount of satellites in dense towns or within buildings could be difficult. That is in addition to problems of increased power consumption and sometimes the size of the mobile cellular phone.

The key advantage of GPS is that it is a proven technology: It provides some level of privacy because the user is in control due to the execution of calculations in the GPS receiver. This can lead to avoiding expensive and time-consuming modifications to the network. The drawback related to the system is that the GPS requires a direct signal from at least three satellites to determine a user's position accurately. This requirement can be hard to achieve when the mobile device is being used indoors or in built-up areas with tall buildings/other obstructions. This leads to the users' growing need for GPS-equipped handsets, which are becoming more popular today with all it brings in terms of device limitations due to size, weight, and battery size.

Differential GPS (DGPS)

Due to variations in atmospheric conditions and clock deviation in satellites, errors are introduced in position calculations resulting in a difference between the actual position and the calculated GPS position. Fixed reference stations, knowing their exact position and equipped with GPS receivers, can constantly compare their real position with the position given by the GPS system. Differential GPS is a system that was designed to eliminate ionosphere, troposphere, satellite clock, and satellite ephemerides introduced to GPS signal for eliminating or drastically reducing errors due to selective availability.

Architecture of DGPS

The idea driving DGPS is that a couple (or more) receivers noticing exactly the same satellites will take a similar measurement and possibly introduce similar errors. Simply by positioning a device termed a "reference receiver" with a known position, it is possible to measure the theoretically correct way of measuring valuations according to the identified position. The subsequent step is to examine theoretical values according to the true position identified. The difference between the two measurements determines the error. The specific error identified used to produce corrections to the receivers (mobiles) when positioned in an unknown location. The concept of DGPS is shown in Fig. 2.6.

Among the crucial issues is that the principle of actual differential measurement may correct merely errors due to the system itself. The satellites are usually orbiting at >**20,000** km above the Earth. The acquired signals, together with errors by receivers positioned at distances, vary between a few hundred meters to several hundred kilometers from each other (at the least with an initial approximation). Nevertheless, local errors due to the receivers or perhaps their local environment are usually uncorrelated and also will not be removed by simply this technique.

Essentially, this rule is logical only for simultaneous, or perhaps nearly simultaneous, measurement, and its particular usefulness diminishes together with a way of measuring a synchronism. Therefore, it is possible to find a couple of restricted variables that decide DGPS high quality: spatial error decorrelation and temporal error decorrelation. In contrast, throughout its simple style, DGPS enables a noticeable improvement throughout basic SPS accuracy down to few meters and even to some millimeters in the most sophisticated forms of DGPS. These types of corrections can be made by postprocessing (raw measurement provided by the reference receivers are recorded and then processed by software). Another

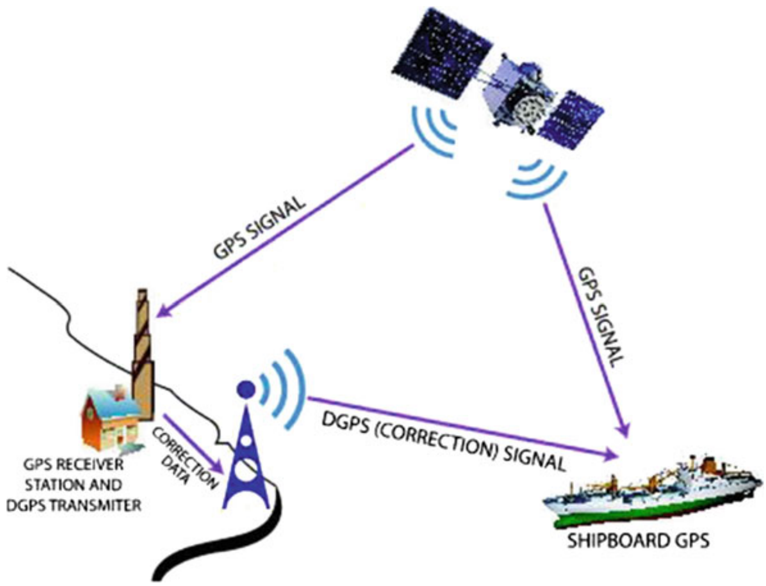

Fig. 2.6 The concept of DGPS

alternative is usually real-time corrections, which are computed on-line and also promptly transmitted to the roving receivers. Roving receivers subsequently use them before calculating their position by having an accuracy that can vary from several millimeters to some meters according to the implementation and the bandwidth of the data link.

Accuracy of DGPS

The accuracy of DGPS typically ranges from 5 to <1 m. Using multiple reference stations in combination with high-quality receivers can determine the position with accuracy in the subcentimeter range.

Application of GPS/DGPS

User applications are the main driver behind the commercial development of GPS products. The number of new applications, each with its unique requirements, increases daily. To make sense of the confusing range of GPS, some applications are as following:

- Land, sea, and air navigation and tracking: These include en-route as well as specific direction-finding, collision avoidance, cargo monitoring, and vehicle tracking, along with research and rescue application. Although the accuracy requirement might be modest and the user hardware relatively affordable, the reliability, strength, and swiftness of results are deemed be at acceptable level.
- Surveying and mapping: All hydrographic or land surveying from terrestrial, airborne or space essentially uses GPS. In addition, geophysical and resource surveys and GIS data-capture surveys use GPS.
- Military programs: Commonly used for civilian purposes, these armed-service GPS programs tend to be designed to be able to address “military specifications,” which place a greater emphasis on system reliability.
- Recreational uses on land, at sea or in the air: This application employs low-cost instruments that are extremely simple to operate.
- Various other specialized uses including time transfer, attitude transfer, determination, spacecraft functions, and atmospheric research: Clearly these purposes demand specifically designed, high-cost systems, frequently having additional functionality, e.g., real-time operation.

Assisted GPS (AGPS)

As GPS antennae and chipsets become smaller and less expensive, it will soon be feasible to integrate GPS hardware into mobile phones. AGPS is a DGPS implementation in which the handset is a mobile phone with an integrated GPS receiver (partial GPS) and in which the telecom network of the operator is used to communicate correctional DGPS data to the handset. Thus, assisted GPS is a combination of several techniques:

1. A mobile telephone network such as GSM.
2. Mobile phone equipped with a GPS receiver.
3. A DGPS network for GP-correction purposes.
4. A location server.

Components of AGPS

The cell base station of cellular telephone system associates with a few DGPS reference stations using an area server. The rectification data obtained from the GPS reference network are then transmitted to the cell telephone GPS receiver. A cellular telephone location-based application is used to help quick start-up and to build the sensor affectability as shown in Fig. 2.7. Acquisition time is diminished from minutes to seconds on account of the forecast space by the receiver and network.

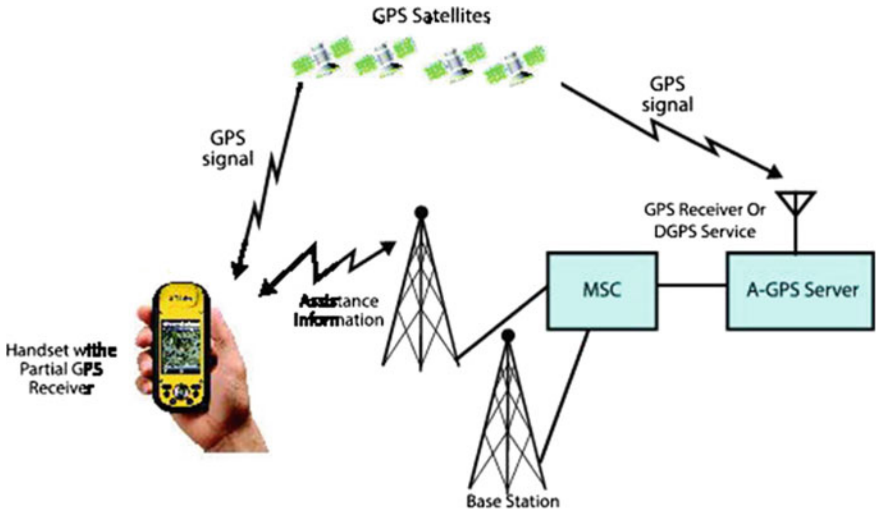

Fig. 2.7 A-GPS components

If the GPS receiver does not know its approximate location, it must seek the whole code phase and frequency space to find the visible satellites. In addition, the relative movement between the satellites and receiver make the search considerably time-consuming. The time-to-first-fix (TTFF) for a noninitiated GPS sensor is approximately 60 s.

By transmitting assistance data over the cell network, the TTFF can be reduced to a few seconds. This is accomplished by essentially lessening the search window of the code phase and recurrence stage by sending exact estimations of these parameters to the handset from the system. There are two options for execution:

Network-Based/Handset-Assisted

The handset is equipped with a GPS sensor (not being a GPS receiver!), which is clearly not a fully functional GPS receiver. A short assistance message to the handset, consisting of time, visible satellite list, satellite signal Doppler, and code-phase search window, is transmitted over the network for assistance. These parameters help the embedded GPS sensor reduce the GPS acquisition time considerably. These assistance data are valid for a few minutes. The handset calculates the transmitted pseudo-range data back to the network. After receiving the pseudo-range data, the corresponding network processor or location server estimates the position of the handset.

A fully functional GPS receiver can be installed in handset systems. As opposed to the network based/handset-assisted approach, the handset can calculate satellite positions by itself. At the start-up setting, more data in the form of precise satellite orbital elements must be received by the handset than are required for the network-based/handset-assisted approach. When ephemeris data transmitted to the handset, it is valid for 2–4 h and can be updated as necessary over time. That makes subsequent updates rare once the handset has the data. In addition to point-to-point transmission, it also includes using a broadcast channel to distribute these data efficiently to all devices in a network. In the case of requirement of better position accuracy for certain applications, differential correction (DGPS) data must be transmitted directly to the handset at approximately 30-s intervals.

Accuracy of AGPS

AGPS provides accuracy ≤10 m outside and 50 m indoors, but is a relatively expensive solution because of the modifications performed in the software and hardware for both the communication network and the cell phone mobile device.

The key advantage of AGPS is its superior accuracy, availability, and coverage with a very short TTFF. This allows for increased accuracy in mapping and building spatial databases and can lead to minimal impact on the device battery life. The implementation of AGPS leads to shared cost between mobiles and the network. This can result in various system evolving with network-upgrade location data shared between users and the network operator where users can withhold data for privacy reasons and an operator can restrict assistance to service subscribers. The air-interface traffic is optimized by distributing data and processing between the network and mobile devices. The drawbacks of the system is that it increases the signal load on using network assistance; moreover, it requires usual the standards update for mobile handsets to allow for delaying, deployment, or upgrades.

Application of AGPS

Various geo-location–based applications are imagined for the eventual fate of a GPS other than emergency services. These applications incorporate system enhancement where spatial-temporal outside activity conveyance is used as a part of the arrangement, outline, and operation of remote systems. Examples include information services, which provides clients with directions to various locations; tracking personnel, vehicles, and assets in managing organization operations; and location-sensitive limitations for billing of mobile users and clients to enable more accurate billing schemes for wireless service providers.

Wide Area Augmentation System (WAAS)

WAAS is a GPS-based navigation and landing framework developed by the U.S. Government Aviation Administration (FAA). It provides precision guidance and direction to aircrafts at airports and airstrips where there is no precision-landing capability. A Satellite-Based Augmentation System (SBAS), e.g., WAAS, gives vital location information capacity.

Architecture of WAAS

Twenty-five Wide Area Reference Stations (WRS) were the foundation of the phase 1 WAAS. Other components include two Wide Area Master Stations (WMS), a Terrestrial Communications Network (TCN), two Geostationary Earth Orbit (GEO) transponders, and four Ground Uplink Subsystems (GUS).

A collection of observable data are obtained primarily by WRS sites throughout the country. The data collected by the WRSs are routed through the TCN to the WMSs. The WMSs focus on the reliability of differential corrections as well as residual errors for each monitored satellite and each predetermined ionospheric gridpoint (IGP). According to WAAS specifications, the process of formatting messages from each WMS takes place. These are sent to the GUS and uplinked to the GEOs. The GEOs broadcast the WAAS messages to the users as shown in Fig. 2.8.

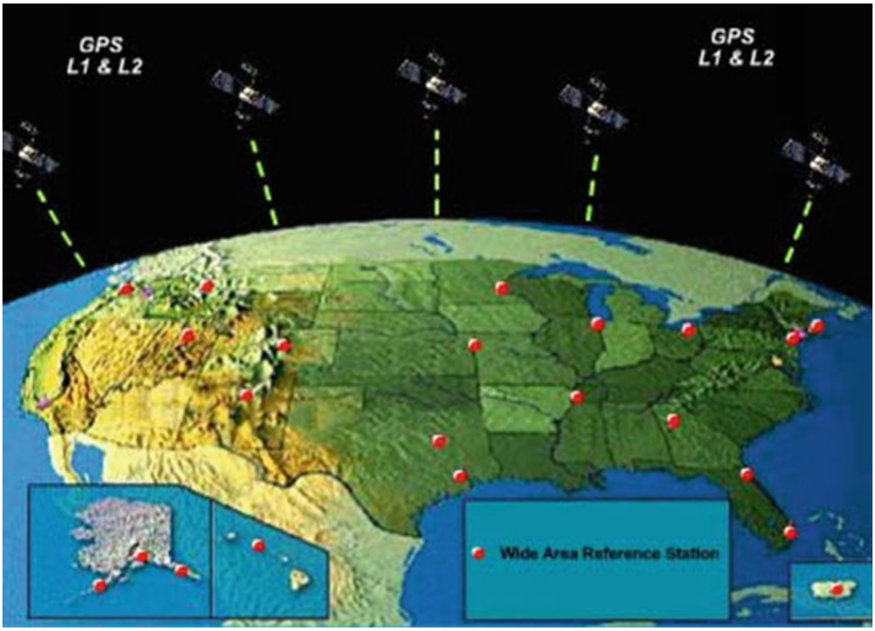

Fig. 2.8 WAAS master station (WMS) distribution in the USA (Image Courtesy of faa.gov)

Accuracy of WAAS

Improvement in accuracy is usually approximated to be within 7 m. WAAS employs geostationary satellites over the equator, which makes it easily blocked in North America due to terrain obstructions. Users may have a temporary loss of WAAS support, especially in wooded areas.

Application of WAAS

The WAAS permits GPS application as a key means of navigation from takeoff through a category-I precision approach. Additional modes of transportation also use the improved accuracy and reliability, availability, and integrity that WAAS offers. The WAAS broadcast message help improves GPS signal accuracy and reliability from 15 m to approximately 7 m with the SA turned off.

The main advantages of WAAS in civil aviation are significant. WAAS certainly improves efficiency involving aviation operations as a result of its greater runway capability and the reduced separation requirements in which there is permit-improved capacity in a given airspace without greater risk. This allow for more direct en-route flight routes and updates and provides new precision-approach services, which results in a reduced number of as well as simplified equipment aboard airplanes. This presents significant cost savings to authorities due to the elimination of maintenance costs connected with older, more valuable ground-based navigation aids.

GLONASS

After the development of the U.S. GPS, the first satellite of the Russian satellite navigation system GLONASS (Global Routing Satellite System) was launched in 1982. Ever since then, it has been implemented with desire for geodetic purposes and also within the navigational world. One of the major features of GLONASS is that it is the only satellite navigation system that did not provide an intentional degradation of the civilian navigation code. That was modified in May 2000 after the U.S. announcement of its intention to stop the use of Selective Availableness (SA) for GPS and thus certainly would not intentionally disturb the civilian signal in any way.

Nonetheless, GLONASS has an advantage when it comes to the degradation of system performance or denial of service: Military code is superimposed on both frequencies. For GPS, the military codes are encrypted, whereas the comparable codes for the GLONASS system are accessible although the Russian authorities do not propose their use. Another advantage for GLONASS is the higher inclination (64.8°) for the satellite orbits, implying better satellite availability at higher latitudes.

GLONASS, like GPS, is intended for both military and civilian use. For the military user, it is not advisable to transmit signals to locate the position because an opponent may very easily intercept the signals. As an alternative, it is favorable to rely merely on receiving signals while preserving radio silence. GLONASS as well as GPS are designed such that the user performs passive measurements of pseudo-ranges toward three or perhaps preferably four satellites. That permits the user to acquire receiver-clock and two- or three-dimensional positions.

Galileo—European Satellite Navigation System

Galileo is an initiative connected with the European Union, including a venture with the European Space Agency (ESA) as well as the European industry, to launch a European-financed global satellite navigation system under civilian control. The need for a European satellite is justified by the growing market for satellite data and information in Europe. This rapid increase comes from the growth of the satellite navigation market from less than 1 billion Euros in 1999 to >8 billion Euros in 2005 to an expected >20 billion Euros by 2020. The ESA began establishing Galileo satellites in 2004, has and had an entire constellation to start off the functional program in 2007. With advanced capabilities in high-precision navigation, positioning, timing, and integrity of information, it is satisfactory to the user community.

The Galileo constellation is comprised of 30 satellites with medium earth orbit (MEO) only. The 30 Galileo satellites will be three orbital airplanes inclined at 54° and an altitude of approximately 23,000 km. It is the simplest system to launch, operate, and maintain, and it provides greater reliability of continuous operational service. Galileo satellites weigh approximately 650 kg when in orbit and generate approximately **1500** W of electrical power. Much sophisticated technology has been built into Galileo including high advanced atomic clocks, which give giving greater accuracy stability as well as low power requirement because it is a lightweight system.

Network-Based Positioning System (NBPS)

In NBPS, the position is calculated at a unit that is part of the cellular network. After calculation, the position is transmitted to the mobile handset. Implementation of these techniques requires various degrees of hardware and/or software modification to the handset, network, or both. In the case of the network, position calculation units, as well as protocols to exchange position information with the handset, must be included in the network. The technologies that are used in NBPS include the following:

1. Cell of origin (COO)/cell-ID (CID)
2. Signal level
3. Angle of arrival (AOA)
4. Time of arrival (TOA)
5. Time difference of arrival (TDOA).

Cell of origin/cell-ID is the most fundamental way for locating a mobile phone: Simply find the cell area in which the phone is being used. The position of the antenna can then provide an estimate of the location of the caller. Because this information is already available in cellular systems, this method can be used instantly. The accuracy of COO/CID depends directly on the radius of the serving cell, which may vary from 50 m indoors to 150 m in urban areas up to 30,000 m in rural areas. Thus, the accuracy of location determination varies with the area, which renders pinpointing the location of a caller imprecise. One other effect is that due to propagation effects, the serving cell is not always the nearest cell, which further degrades accuracy. Key advantages of the COD/CID are that it requires no alterations to handset or network, low cost, and usable for all existing equipment. In addition, it requires no calculations and provides fast response capability. However, questionable accuracy is an issue with this positioning technology.

The signal-level technique makes use of the fact that the amounts of energy in the signal decrease significantly when the distance between the antenna and the mobile phone is increased. Under ideal conditions, signal-level contours around an antenna are perfect circles. If the relation between the signal level and the distance is known, then this could be used to determine the distance from a particular antenna. Once the signal levels from three different antennae can be measured, the location of the mobile phone could be pinpointed as the unique intersection point of the three circles. In terms of accuracy, this technique is far from ideal because signal levels around an antenna are not perfect circles. Signal levels vary significantly due to multipath traveling (reflections of objects such as buildings), interference with other signals, and passage through walls, foliage, or glass-and-metal vehicles. This phenomenon can be corroborated by any cellular user who has seen the signal-strength bars on a mobile phone display fluctuate, even when the phone is not moving. Signal levels are also affected by seasonal variations in weather and changes in foliage. All of these effects result in random variations in signal strength that can not be predicted. As a consequence, this method can only be used in controlled situations with a clear view of the antennae. The advantage is that it is easy to implement in GSM, with a low-cost process for improving the accuracy of cell-ID location, and it provides somewhat good coverage, which supports available existing GSM mobiles. However, it difficult to achieve high accuracy because it has the least reliability compared with other methods, which makes it not effective when used. Moreover, it is affected by the shadow of large objects whether used indoor or on the road.

The angle-of-arrival (AOA) technique is based on angle calculation of the signal as it arrives at a base station. A minimum of two stations is required to determine and locate the position of the mobile phone, i.e., at the intersection of the lines. For higher precision, more than two stations can be used. A complex calibrated antenna array at each receiving site is used to measure the angle of arrival. Even in an antennae array, in which the antennae are separated by only a few inches or few feet, there is a small but measurable difference in arrival times and the electrical phase received at each antenna. These are differences compared with estimating the direction from which the transmission is originating. Its accuracy depends on geometry, precision, and the resolution of AOA measurements, distance of the base from the mobile station, and multipath propagation. The advantages of this technique is that it requires limited cell coverage of a minimum of two cell sites to determine a user's location, and it requires no clock at the cell sites because time is not part of the calculations. It also allows for easy updates to the location once there is change in the network connectivity, and it does not require constant modification to the handset. However, the main drawback to this system is that the accuracy is affected by the distance between the device and the base station network despite some antenna modification to deal with the issue. This means that it requires significant infrastructure costs for the installation of additional antennae and location equipment at each cell site, which makes it vulnerable to different errors, such as multipath interference, caused by the reflection of the actual signal from the surrounding objects. That is problematic because this technology uses the direct line-of-sight signal. Therefore, this technique is barely usable in dense urban areas where the line of sight to two base stations is seldom present. It also jeopardize privacy of the users because it provides constant tracking of each user whether or not the mobile phone is being used.

Time of Arrival (TOA)

In the time of arrival (TOA) technique, the radio waves travel at the speed of light, which is approximately 300,000 km/s or approximately 300 m/μs. TOA is based on measuring the absolute time difference of the signal between the mobile phone and multiple base stations. This technique requires that the exact starting time of the transmission must be known and that all base stations in the network be accurately synchronized with, for instance, an atomic clock. Synchronization must be this precise because a 1-μs difference can result in a position error of 300 m. All base stations are fitted with location measurement units that calculate the distance to the mobile phone by dividing the traversed time by 2 and multiplying the result by the speed of light. Each calculation places the location of the mobile phone in a circle, centered at the base station, with the range as diameter. The range from three receiving antennae is needed to determine the location unambiguously. Its accuracy is relatively small, and it is possible to connect and improve the accuracy based on the network. The drawbacks of this system is that it has low accuracy.

Time Difference of Arrival (TDOA)

TDOA technology uses relative time measurements rather than the absolute time measurements in the TOA technique. Transmission of an unknown starting time is received at separate receiving antennae at different times. A technique called "tri-lateration" is used to determine the location of the mobile phone: The times from pairs of receiving antennae are subtracted to calculate the relative timing. Each time difference from each pair of antennae places the transmitter on a hyperbolic curve. The location of the mobile phone can be determined unambiguously from the intersection of the two hyperbolic curves. The accuracy of the system is a function of the spatial locations of the corresponding base stations. TDOA is often referred to as the "hyperbolic system" because the time difference is converted to a constant distance difference to two base stations to define a hyperbolic curve. In the world of GSM, TDOA is called "enhanced observed time difference" (E-OTD), and it offers an accuracy of approximately 60 m in rural areas and 200 m in very urban areas.

The advantages of this system is that the handset used can allow for continuous tracking of the user's location; it also allows for easy updates to the location-determination system. However, it is costly and requires rapid cell-site modification in terms of infrastructure. In addition, it has some difficulties in certain environments due to signal limitations, which requires advanced infrastructure. It is also prone to multipath interference caused by reflection of the actual signal from surrounding objects. That is problematic because this technology uses the direct line-of-sight signal. Therefore, this technique is barely usable in dense urban areas where the line of sight to two base stations is seldom present.

Applications of NBPS

There are many applications for network-based positioning technology including enhanced 911 services, traffic information and monitoring, enhanced 411 directory/information, and in-vehicle navigational assistance and roadside assistance. It is effective in location-based billing and fleet tracking as well as in field-based wireless mapping applications of telegeoinformatics and LBS.

Radio-Based Positioning System (RBPS)

RBPS technology uses radiofrequency (RF) to determine position. The methods it uses are triangulation, scene analysis, and proximity. Some of the technologies discussed as follows.

Real-Time Locating System (RTLS)

For centuries, enterprises have been faced with the challenge of locating and tracking inventory and assets with traditional methods. Receiving, storing, and issuing inventory items and specifying their location are difficult tasks when dealing with huge warehouses and mega stores regardless of whether a scroll or quill, a clipboard or pencil, or a bar-code scanner and database is used. The process of RTLS allows you to track, place, and assess inventory.

Application of RTLS

Complex supply chains along with n new mixture of high-value products in a large storage space or mega stores: These represent good candidates for RTLS. Manufacturing, travel, and logistics (as shown in Fig. 2.9), along with health care, may also be leading markets that could take advantage of methods using RF hardware along with the application to handle resources along with inventory.

RTLS Versus GPS

RTLS and GPS both provide location information. GPS, in general, communicates with the receiver through a signal, and it helps with performing different types of measures that define the location of each component of the system. RTLS merely

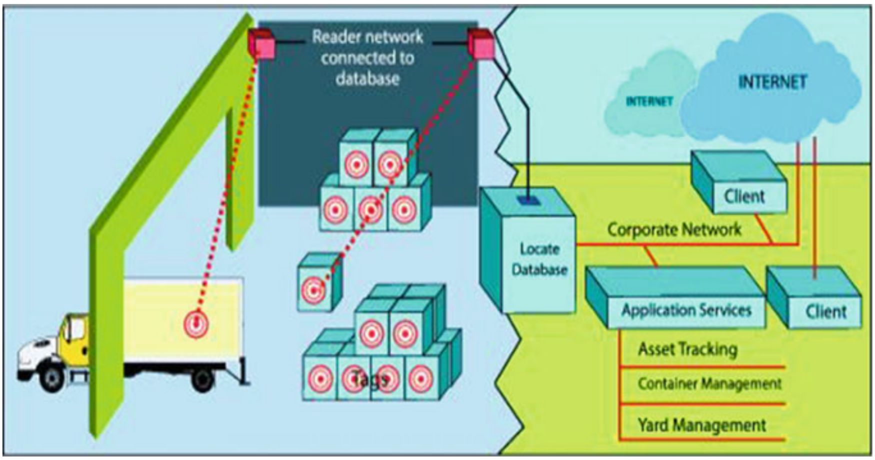

Fig. 2.9 Example of RTLS

deals with the location of the tracked item and notifies the user of the location. In a sense, RTLS is a static positioning technology. Other points of distinction are as follows:

- GPS signals cannot penetrate building, walls, and ceilings, thus making indoor use of no consequence.
- GPS resolution may vary, but it provides accurate location information.
- GPS receivers tend to consume energy, whereas while RTLS tags can use batteries for up to 7 years.

Radiofrequency Identification (RFID)

RFID utilizes radio stations' consistent communication to immediately distinguish, monitor, and take care of materials, individuals, or perhaps animals. The unaggressive low-frequency "magnetically coupled" RFID method comprises a couple of parts, some audience and some point. A "tag cloud" is normally placed on materials or perhaps animals that need proper ID. The tag cloud is bundled in an electric circuit (transponder) and returns on the antenna-capacitor circuit. The tag cloud usually is a smaller, newer radio station transmitter and receiver. Tickets are usually powered through the RF discipline generated through the audience. On becoming "powered-up," the actual point may continuously broadcast by simply dumping the actual new RF electrical power discipline, their facts as explained in Fig. 2.10. Through pushing the actual incoming RF electrical power field, many tag clouds might be written in the field. The RF audience offers three major capabilities: energizing, demodulating, and decoding. By using an antenna-capacitor circuit, it gives off some low-frequency radio stations. That is certainly used to power up to the actual point. The info routed through the point must is usually demodulated like

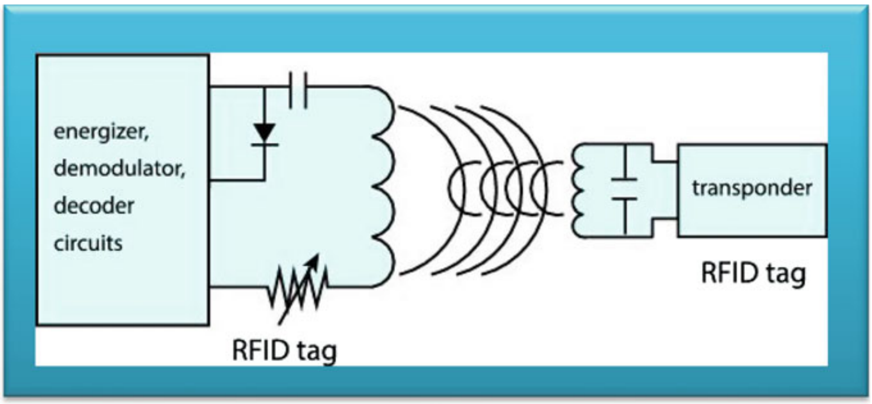

Fig. 2.10 Architecture of RFID (Courtesy of Georgia Tech. www2.ece.gatech.edu)

a FEEL radio station. The encoded information is decoded through the audience on-board microcontroller and prepared by way of a preventing computer.

They advantages of RFID products compared with other identification technologies includes the fact that they are passive RFID systems that offer many benefits including no requirement for batteries and tags that can be embedded in variety materials because they come in different shapes and sizes. They require no line-of-sight or wear because they are part of a field, which makes them readable even if they are covered with dust or dirt. In addition, they do not need to be worn and are mostly indestructible with an unalterable permanent serial code that prevents tampering. RFID systems are usable almost anywhere. Some current uses of RFID include inventory control, facility access control, livestock tracking and identification, solid waste management tracking and control, laboratory-sample tracking and analysis, data logging for location and time, as well as traffic-violations tracking, vehicle identification, and building security and asset tracking.

Summary

GPS and the Internet have two things in common: both are free, and both (will) have an enormous impact on everyday life. Recent developments have shown that combining the two may eventually result in a worldwide web of reference stations, thus establishing a global-positioning system that provides high accuracies to all users anywhere and anytime. A GPS technology overcomes the downside of the conventional GPS solution and achieves high location accuracy at a reasonable cost. WAAS improves basic GPS accuracy vertically and horizontally. The system availability comes through the use of geostationary communication satellites (GEOs) carrying navigation payloads, which provide necessary integrity information about the entire GPS constellation.

NBPS can address both consumers' requirements as well as a broad range of professional applications. NBPS technology will be a competitors to GPS if the mobile phone is the only device to access LBS. The accuracy of NBPS using each location method depends on network density, the radio-propagation environment, and algorithms. No single technique is superior regarding accuracy, response delay, coverage, capacity, and implementation costs. Different techniques are usable in various settings (indoor, urban, and rural) and for different services.

RTLS and RFID are RBPS that used radiofrequencies as a system component. RTLS is RFID upgraded to produce instant location information. Items tagged with conventional RFID are read when the reader is close to a tag or a tagged item is passed near a reader. RTLS allows a reader unit to "see" the actual location of a tagged item without the tagged item being near the reader. Using first readers placed on property, tags are located using a triangulation system. Tagged items may be as small as a tool or as large as a trailer truck.

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