Integration of Wireless Technology with GIS & its Applications

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Abstract:

Over the past decade, Global Navigation Satellite system (GNSS), Geographic Information Systems (GIS) and wireless technologies have advanced in terms of reliability, accuracy and cost effectiveness. These technologies have become mainstream and have led to the development of location-based services. Location based services provide personalized services on the basis of the current position of the subscriber, calculated using GNSS. As of now, only the United States NAVSTAR Global Positioning System (GPS) and the Russian GLONASS are global operational GNSS's. India's regional satellite navigation system GAGAN can be viewed as the first step towards introduction of modern communication, navigation, surveillance/Air Traffic Management system which will be operational in the year 2014. The calculated position using satellite system can help in routing, navigation and network planning related applications. The integration of Wireless technology and GIS can help us to build an internet map server (IMS). An internet Map server (IMS) is an online server that can be used to store the spatial data from the GPS units or other mobile GIS units i.e. Arc Pad, ArcGIS for Mobile. In this paper, we brief on the advancements in wireless technology and discuss the applications of wireless GIS.

Keywords: Global Navigation Satellite systems (GNSS), GIS, Mobile GIS, Wireless communication, radio network, wireless link, Internet Map server(IMS), air traffic management (ATC), Network planning

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Introduction

With the advent of smartphones and tablets, there is an increase in the demand of commercial location-based services. It has subsequently led to the need for more accurate positioning services which is a combination of global navigation satellite system (GNSS), Wireless communication and GIS. Due to the technology advances driving GPS, the receiver's position can be determined to an accuracy of less than a meter in a noise-free environment. Also, the development in wireless communication technology such as 4G, Wimax has led to the high speed data transfer between mobile units. To harness the location-based services, the combination of GNSS, Wireless technology and GIS creates interoperable services for mobile units. We name the combination as wireless GIS. The applications of Wireless GIS are multi-disciplinary, from designing radio networks to creating wireless links for military services, Air-traffic control (ATC), city traffic planning, forestry applications etc.

GNSS Positioning Principle

The basic concept of point position depends on the trilateration between the receiver and the satellite. Range measurements from at least four satellites is needed is determine the four unknowns X, Y, Z and receiver clock offset (Δ). The range is measured by the receiver and the coordinates of the satellite are extracted from the navigation message. The basic concept of position determination is to calculate the time difference between the transmitted signal and received signal. The time difference is then multiplied with the velocity of light to obtain the distance of the receiver to the satellite. The non-GNSS positioning solutions such as Cell-ID etc. are not very popular because of the low positioning accuracy. Due to advances in GNSS technology one can add points and contacts, update GPS maps on a touch of a button, that has made the routing and navigation applications much easier.

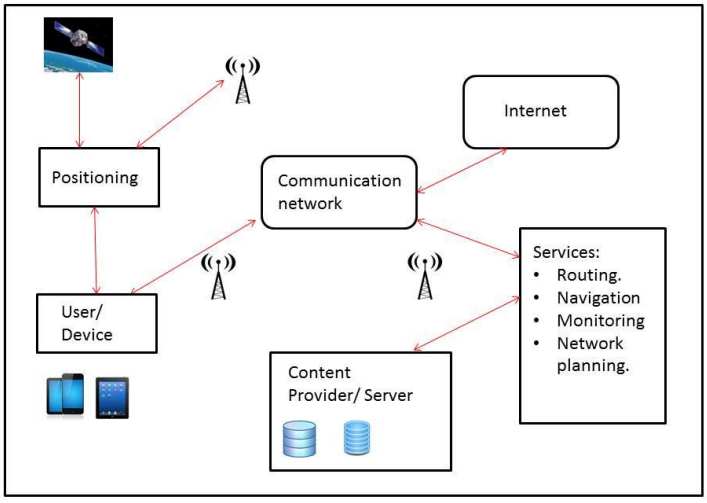

Fig.1 Location-based services and GNSS principle

Methodology

With the help of GNSS, the user's device position can be determined precisely. The user can then connect to the internet via advanced wireless technologies such as EDGE, 3G, and WiMAX etc. After establishing the connection, the user can access the services present on the internet map server. Also, the GPS maps can be edited and updated back to the server. ArcGIS Online provides a managed infrastructure for organizing and sharing geographic information in the cloud. This infrastructure gives organizations the ability to store, manage, and host their mapping services, easily publish their geographic content, and off-load selected processing activities using cloud services. The users can access and use ArcGIS Online basemaps and thematic maps and develop real-time web GIS services.

Applications

i. Air traffic control

Due to the rise in urbanization, airfield operations are getting complex and there is a need to make the airfield operations safe. Wireless GIS mitigates the human error and training issues and ensures safer airfield working environment. The following information is needed for successful airfield operation:

a. Increasing situational awareness: As the GPS is mounted over the vehicle, it collects the current location of the vehicle and when combined with GIS technology, it can help us to visualize what their exact position is and graphically resolve traffic issues, by visualizing them on a digitized map. Also, as the vehicle moves the map and related assets also moves.

b. Navigation:
   - How long it will take to get from A to B.
   - To identify busy routes
   - In case of fog, atmospheric interference or any emergency, the GPS and GIS can track the vehicle and then through audio-visual commands, the alternative route can be suggested and the emergency teams can come into action quickly. Moving to a safer route is possible by following the commands from the control station and tracking the movement of the vehicle.

c. Reducing airfield incursions: The vehicle's speed, direction and position are estimated by the GPS receiver. If the vehicle enters a hold/stop line from a non-active side, a geo-fence can be quickly generated to prevent the air craft from entering into that area.

d. Issue identification: The advantages of "stamping" the exact location of the friction/temperature data as it is collected by/from the equipment. A very accurate location of the data, which is also date/time initialized, is created. This derives many benefits including the ability to objectively demonstrate due diligence. This information now allows for real-time decision making with both economic and environmental benefits (i.e. we only have to anti-ice the touch down area and not the whole runway). Using the GIS interface as a guide, operators can task chemical applicators to apply chemicals at

pre-defined rates in predefined areas. This allows for a greater level of confidence in where and how much chemical is applied.

ii. Designing Wireless links

For radio network planning, we need geographical data such as terrain data, topology, and demographic data about the location to find out the best suitable position for antenna setup. The network design includes calculation of factors such as the received signal strength, distances between existing nodes of a network, interference from obstructions. GIS scores over traditional network design because it considers geographical factors, security and confidentiality of network, and logging the data about the performance of the existing nodes continuously. We can design network in two phase's i.e. pre-design phase and the actual design phase. In the pre-design phase, the digitized maps depicting geographic information such as hills, mountains and vegetation etc. are analyzed. Also, factors like required coverage area, a number of users in the area, traffic demand throughput, and number of existing sites are stored. ArcScene can provide 3D View of the antenna coverage, antenna tilt and azimuth required for better coverage. Also, the information about the antenna parameters can be stored on the field with the help of ArcGIS for mobile and can be uploaded on the cloud via ArcGIS online. The stored information can be later retrieved from anywhere by connecting to the cloud server. The earth's curvature, Fresnel's distance is also taken into account while calculating the line of sight distance for important communication links. The pre-design phase provides the various inputs and requirements which are to be utilized in the actual design phase. The actual design phase points out the accurate coordinates and geographic location on the map where the new antenna system is to be installed.

The following calculation results are generated after the design phase:

- Received signal strength and serving areas for best and following servers.
- Ec/No (amplitude of signal/noise signal amplitude), pilot pollution, soft and softer handover
- Cell loading, throughput for DL (downlink) and UL (uplink), number of users per cell
- Traffic service areas for DL and UL, received Eb/No and required power of user equipment, total noise and noise rise, HSDPA SINR (Signal to noise ratio) and data rate.

Statistical analysis is also performed on random users to calculate the average signal strength using GIS functions. After the design phase, we can calculate optimal number of sites and sectors, sector height, transmitting power, antenna type and orientation for required serving area.

iii. Environmental monitoring

To respond to the need for analytical and web based tools for processing remote sensing imageries, ArcGIS mobile provides the architecture which is useful for natural habitat conservation and land management programs. The pocket PC's, smartphones which do have an inbuilt GPS can demonstrate the real time monitoring and change detection patterns which are required in natural habitat reserves by resource managers. The mobile remote sensing and GIS data collection and analysis solution provides a user-friendly, easy to use interface that allows park rangers and resource managers to access and analyze land-cover changes and remotely sensed images in the field.

The most interesting feature of this application is the establishment of a wireless link between the Mobile GIS receiver and the cloud server i.e. ArcGIS online. In case, where the imageries are large in size, they can be stored to the cloud server database provided that the Mobile GIS receiver is connected to the internet. Also, the maps and its attributes can be edited and updated directly to the server since mobile GIS receiver provides the Map editing tools. Using geotagging option, one can add images as a separate layer or attach to the attribute itself. We can also add location of new plants in a forest with the help of GPS and can send the updated information back to the server. With the help of Digitized GIS maps, one can delineate the forest area with the surrounding area and can track the various endangered species and can build a database regarding the same. A mobile application can be developed storing information about the land use and whether it is protected area/closed area/damaged area. This information can be uploaded to the server by creating a web-based GIS application. Using ArcGIS Online, the information can be retrieved by multiple users and can be used in developing various web applications.

iv. Vehicle Navigation

Nowadays in urban areas, we often face traffic jams or when we visit a new place we are unaware of the necessary route. Mobile GIS and GPS services collaboration can help in the decision-making using location based services. The user can get its approximate location using the inbuilt or external GPS system to the GIS unit. The user thus connects to the GPS via wireless link and resolves its queries. The advanced wireless technology has helped the user to receive audio visual commands in addition to the digital map of the location. As the vehicle moves, the map and its related attributes also moves with it. Necessary arrow symbols are highlighted on the digitized map so as to make the navigation easier. Since the Speed, direction and distance of the vehicle are calculated by the advanced GPS receiver, the application can solve the user's time related queries to reach to its destination address.

v. Emergency Management

A software package can be developed with the help of Web GIS services and GPS to track the vehicle movement and in case of congestion/traffic, the local traffic police can help in suggesting alternative routes. The rate of accidents can be reduced and better emergency services can be provided. Also, a database can be maintained which contains the data about hospitals, road network, automobile workshops etc. The database part is very critical in this application. There are two different types of database, the spatial database (street, district, etc.), and the entity data base containing information about the vehicle. In case of a vehicle breaking down on an highway/expressway, it is required that the emergency team gets the exact location of where the vehicle is, and look for a crane to pull that vehicle from the road quickly so that any accident can be avoided. The database can be developed containing information about the number of accidents occurring over a street network. When the number of accidents exceeds a specified limit, the team should arrange an alternative route. The accident information, its locational data (street, town, and district) should be stored to the server from where it can be retrieved and reviewed later.

Wireless communication technology employed in Location based services

The Global system for mobile communication (GSM standard) can be described as a digital, circuit-switched network optimized for full duplex voice telephony. This was expanded over time to include data communications, first by circuit-switched transport, then packet data transport via GPRS (General Packet Radio Services) and EDGE (Enhanced Data rates for GSM Evolution or EGPRS). The 3GPP developed third generation (3G) UMTS standards followed by fourth generation (4G) mobile telecommunication technology.

i. **GSM and EDGE**: The radio frequency band utilized by GSM is the 900MHz spectrum and later introduced on the 1800MHz band. EDGE combined with the GPRS 2.5G technology is called EGPRS, and allows peak data rates of the order 200 KB/s. EDGE shows slightly better system spectral efficiency than the original UMTS and CDMA2000 systems, but it is difficult to reach much higher peak data rates due to the limited GSM spectral bandwidth of 200 kHz.

ii. **3G** (Third Generation): The 3G standard utilizes a new technology called UMTS as its core network architecture - Universal Mobile Telecommunications System**.** The radio frequency band utilized by UMTS is the 2100 MHz spectrum in addition to the 900 MHz spectrum. 3G telecommunication networks support services that provide an information transfer rate of at least 200 KB/s. Later 3G releases, denoted as 3.5G and 3.75G, also provide mobile broadband access of several Mbit/s to smartphones and mobile modems in laptop computers. 3G finds application in wireless voice telephony, mobile Internet access, fixed wireless Internet access, video calls and mobile TV.

iii. **4G** (Fourth Generation): It is a successor to the third generation (3G) standards. A 4G system provides mobile ultra-broadband Internet access, for example to laptops with USB wireless modems, to smartphones, and to other mobile devices. The 4G network is based on LTE-Advanced - 3GPP Long Term Evolution. LTE is a series of upgrades to existing UMTS technology and will be rolled out on existing 1800MHz frequency band. This new network boosts peak downloads speeds up to 100Mbps and 50Mbps upload, latency reduced from around 300ms to less than 100ms. The peak bit rate is further improved by smart antenna arrays for multiple-input multiple-output (MIMO) communications.

iv. **WiMAX**: Worldwide Interoperability for Microwave Access (WiMAX) is a wireless communications standard designed to provide 30-40 Mbps data rates. Fixed WiMAX is also considered as a wireless backhaul technology for 2G, 3G, and 4G networks. WiMAX is based upon IEEE Standard 802.16e-2005, adding support for mobile (soft and hard handover between base stations).

Limitations:

i. GIS data and maps should be periodically updated.

ii. Need to develop standards for GIS data collection.

iii. Limitation of wireless communication as the data uplink/downlink is not possible beyond the coverage area.

iv. In India, only 97,000 out of around 7,00,000 Base transceiver stations (BTS's) are built on UMTS architecture. Since EDGE do not provide high data rate as compared to the UMTS platform, location-based services can't be accessed from rural locations.

v. GNSS positioning services are greatly affected by interferences and noise inherent in the system. The regional navigational systems have to be developed to provide more accurate positioning services which are insensitive to parameter variations.

vi. As the number of active users increases over a wireless network, the data transfer rate decreases significantly in a GSM/UMTS network.

Conclusion:

Increasing demand for commercial location-based services is pushing GPS/GNSS to provide more accurate positioning solutions. The locational data is important for every industry to increase its economic profit, reduce risks and respond to an emergency situation quickly. For military and commercial sector, we need robust wireless links which can be developed incorporating GIS technology. The need to develop mobile GIS solutions which can be embedded into smartphones/tablets is ever growing. The mobile GIS give the flexibility to update GIS data on the touch of a button, carrying portable GIS system on to the field directly and communicating with the cloud server i.e. ArcGIS online. Cell-phone networks provide wireless spatial coverage but lacks in broadband coverage over long distances. MIMO (multiple input multiple output) technique enables different antenna to simultaneously receive and upload data, this has brought a significant revolution and in the upcoming days, we will see low power, high speed wireless technologies coming up in the market.

ArcGIS family software is a prerequisite tool for carrying out the mentioned applications.

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