New approaches in GPS based location systems

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Introduction

Since the completion of the global positioning systems (GPS) satellite network in the early 1990's, there has been a proliferation of applications developed utilizing this technology. While military and defense related applications ruled the roost in the heydays of GPS technology, the last few years have seen most of the applications in the consumer and commercial space. The introduction of products with high volume potential such as cell phone (referred to as 'handset' in the rest of this paper) have given GPS technology a definite niche in terms of market economics. The E-911 mandate stipulated by FCC (Federal Communications Commission, United States) requires every cellular phone to be able to provide their location to assist in dispatching emergency help. This initiative has fuelled the emergence of creative technologies that combine the use of GPS as well as wireless carrier networks to provide high accuracy and reliable position information. This technology is also referred to as A-GPS (Assisted GPS). This paper takes a close look at some of these approaches from a technical standpoint and discusses their merits and weaknesses.

Satellite-based conventional GPS receiver architecture

A GPS user positioning system can be broken into four primary functions:

(a) determining the code phases (pseudoranges) to the various GPS satellites,
(b) determining the time-of-applicability for the pseudoranges,
(c) demodulating the satellite navigation message, and
(d) computing the position of the receiving antenna using these pseudoranges, timing and navigation message data.

Most conventional GPS receivers based on the above principles are often referred to as "satellite-only" receivers. They do all these operations without any external assistance. This approach faces many challenges including (a) low Time-To-First-Fix, (b) low sensitivity, and (c) higher power dissipation. Traditional GPS receivers require from 30 seconds to several minutes to acquire and track satellites, depending upon how much information they have previously gathered. In the case of a cold start, it could take the receiver upto 10 minutes to acquire the first fix. The traditional GPS technology can also have difficulty acquiring signals when the attenuation exceeds 5-10 dB. This makes GPS unusable and unreliable in urban canyons and other areas involving physical obstructions. Moreover, conventional GPS receivers tend to continuously process position data (even when it is not required), thereby consuming more power. These challenges have forced GPS researchers to look at network based solutions that rely on the signal transmitted from the handset and received at multiple fixed base stations, using Angle of Arrival (AOA) and Time of Arrival (TOA) to determine position. Having said that, network-based solutions also face a number of difficulties, including multipath propagation, diffraction, weak signal conditions, base station availability and expensive upgrades. A combination of these two technologies, referred to as Assisted GPS, provides for optimum performance.

Assisted GPS

Although individually inadequate in providing a real-world commercial location solution, network and GPS solutions actually complement one another rather than competing against each other. For example, in rural and suburban areas, not many base stations can locate the handset, but a GPS receiver can often see four or more satellites. Conversely, in dense areas and inside buildings, GPS receivers do not detect enough satellites, but the wireless handset can detect two or more base stations.

A-GPS provides a user with the ability to obtain a location in places where standalone GPS may not work. In these circumstances, the user's position is calculated using information provided by the network. The information can be in the form of time aiding (to narrow the search range of GPS signals), approximate location information or GPS ephemeris data. In most A-GPS systems, signals are collected at the receiver and sent to the network server where a location is calculated using network provided aiding information. The aiding information from the network augments the ambient GPS signals, resulting in better location fixes in environments such as urban canyons and inside buildings. While this technique provides the superior coverage needed for applications such as E-911, it has two disadvantages. First, network assistance is required to calculate a position, making it useless in areas where no aiding information is available. This might include areas with no cellular coverage or even areas without compatible aiding servers in roaming environments. Second, the user's location is calculated on the network, not at the receiver, creating potential privacy issues for consumers. In addition, doing position calculations in network servers makes A-GPS impractical for applications like continuous navigation, which requires position updates once per second since data traffic would be excessive and loss of network connectivity will cause consumer frustration.

One possible approach proposed by GPS researchers is to have a multimode location technology which would allow a GPS receiver to intelligently switch between different modes, ranging from a standalone mode through various aided modes to determine a position based on the application and signal strength environment. This approach would optimize the use of airtime and flexibility depending on the situation. A typical multimodal platform is designed to work with any underlying network protocols, including those where precise time is not available in the network. A multimodal location technology typically offers the following:

(a) Enhanced sensitivity, standalone positioning mode, in which location is computed and displayed locally on the handset. This method utilizes no assistance information from a server or a network and no wireless network connectivity is required. As a result, it is ideal for applications that require continuous or frequent position data in the handset where wireless network connectivity is not available or needed by the user (e.g. to protect the privacy).
(b) Network connected, high sensitivity autonomous positioning mode, whereby location is computed on the handset and sent to a sever, which can provide location sensitive content and services such as mapping information or location of closest gas station. This is a flexible solution for many types of handheld devices where no aiding server is available.
(c) Mobile centric, network-aided positioning mode, in which location is computed at the handset utilizing aiding information from the wireless network or other sources. This mode improves time to first fix and receiver sensitivity and is a reliable solution for high-priority location assistance applications.
(d) Network-centric, aided positioning mode, in which location computation is calculated completely by the server, based on information collected at the handset and the aiding information received from the wireless network or other sources. This mode extends GPS availability and is used in some E-911 implementations.

As carriers implement a range of location based services, location technology must move beyond network resource-intensive applications such as A-GPS. The multimode location technology which has been pioneered by SiRF (GPS chipset company based out of San Jose, N.America) offers carriers the flexibility and scalability they need to offer a wide range of LBS with minimal network impact.

Handset Architecture

Figure 1 (next page) is a typical "handset view" of a network assisted GPS system. The conventional tracking loops are replaced by snapshot memory and fast convolution processing.

At the request of either an external application, or the handset user, the server sends information on satellites in view at the handset's approximate location, including Doppler predictions. After a snapshot of GPS satellite RF data has been stored in the handset memory, the DSP processes the data and returns the pseudorange measurements to the server, along with other statistical information. This snapshot approach allows the handset to gather GPS data when it is not transmitting, thus eliminating potential self-interference. Each of the messages between the handset and the location server is small (50-100 bytes). This represents a significant reduction in required communications bandwidth when compared to delivering differential corrections, almanac, ephemeris and/or satellite trajectory data to the handset.

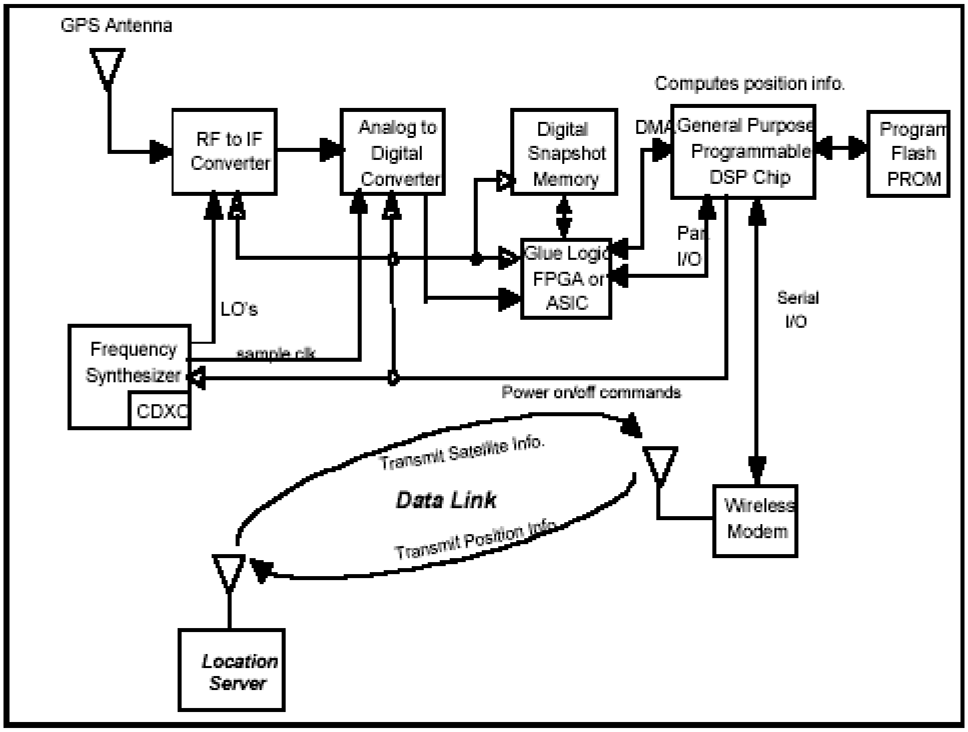

Figure 1 Block Diagram of a typical DSP based GPS processing system

In the system described in Figure 1, received data is down-converted to a suitably low (~ 2MHz) intermediate frequency, digitized and stored in a buffer memory. This data is then operated upon using a programmable DSP IC. Unlike continuously tracking hardware correlator-based receivers, this snapshot processing technique is not subject to the fluctuating levels and changing nature of the signal environment.

This server-aided GPS approach has been pioneered by Snaptrack (The company is now a part of Qualcomm) and improved upon conventional GPS performance by sharing processing and database functions between the mobile GPS receiver/processor (client) and a remote infrastructure (the server and reference network). The result is a highly sensitive, cost-effective, low-power, GPS receiving system that provides first fixes in a few seconds from a cold start, even when conventional GPS is unworkable or unreliable.

Summary

Both network and standalone GPS location technologies have inherent weaknesses, resulting in reduced accuracy, decreased availability and higher implementation costs. Assisted GPS utilizes the complimentary nature of both approaches to overcome situational weaknesses experienced by either network or GPS approaches working alone. The benefits of Assisted GPS approach include maximum availability, increased sensitivity, higher accuracy, lower complexity and a rapid time-to-first-fix. Apart from United States, large-scale adoption of this approach is beginning to happen in Japan where conventional GPS fails to perform in urban canyons like Tokyo. Attempts are being made to ensure that this technology is supported on a multitude of wireless networks deployed worldwide such as GSM, CDMA, TDMA, 3G etc. Successful compliance of the E-911 mandate by the end of 2004 will give more tooth to these advancements especially in United States. User experience and economics of incorporating this approach in a client/server environment will eventually drive this technology.

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