論文の内容の要旨

論文題目　GPS Performance Improvements by Utilizing Networks
（ネットワークの援用による GPS 性能向上に関する研究）

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GPS provides accurate, continuous, world-wide, real time, 3-dimential position and velocity information. In recent years, the usage of the GPS has become nearly ubiquitous. This is driving for some new challenges such as high precision, high sensitivity and fast positioning for GPS performance. Nowadays our society is evolving to a ubiquitous network society. Various kinds of networks exist in our life. In this thesis, we proposed two kinds of system to improve GPS performance with the help of network.

Differential GPS was proposed for the applications of high precision measurement, land survey and so on. By using correction data from reference stations at known locations, DGPS accuracy is improved to on the order of meter and RTK-GPS can provide precise positioning service on the order of centimeter. In a Differential system, how to transmit the correction data from reference station to the user is extremely significant. We proposed differential GPS correction data dissemination via geostationary satellite communication link and Internet for high accuracy Differential GPS.

At least 4 visible satellites are indispensable when doing positioning by GPS. In recent years, the positioning needs is arising from urban canyon and indoor environments, where the conventional GPS receiver can not catch enough satellites. Assisted GPS technology makes indoor positioning possible and fastens positioning by using the assistant information transmitted from the assisting server. Comparing to the high level SNR signal processing time, the high-sensitivity receiver has to do longer time integration during acquisition process to catch weak signal of satellite. Therefore, the performance parameter TTFF (Time To First Fix) will become to a large number. To reduce TTFF of the high-sensitivity receiver, we proposed an acquisition scheme based on timing-synchronized 3G (third generation) network for AGPS receiver.

(1) Differential GPS Positioning via Geostationary Satellite Communication Link and Internet

In DGPS and RTK-GPS, the user uses the correction data transmitted from the reference station to do high precision positioning. In DGPS, the reference station broadcast the correction data via FM radio and medium wave. FM radio service has been used in car-navigation system and covered almost whole country. Medium wave service is only for marine navigation that users can not use it inland. Country wide RTK-GPS correction data service in Japan is still not constructed yet. The cellular phone network, specific low power radio, audio sub-carrier channel and mobile radio communication link for business use have been researched as data link. However, their applications were constrained by data transmission rate, coverage and necessary special receiver.

We proposed geostationary satellite communication link and Internet as new type data link. The

geostationary satellite communication link has some merits as follows: First, satellite communication can cover wide area and unlimited number of user can receive signals with their receivers; second, at least 64kbps data transmission rate is available. However, satellite communication needs expensive VSAT (Very Small Aperture Terminal) and parabola antenna. They are heavy and not convenient to setup. A transmission system is suggested and a DGPS positioning experiment is carried out via geostationary satellite communication link. The experiment results are evaluated. One other kind network we chose as data link is Internet. The Internet covers the entire world and if the user has an IP, he can connect to Internet easily. Because bi-direction communication is possible, the user has flexibility of selecting reference station, correction data type and so on. However, the most critical characteristic of Internet is latency, which will have a great effect to the differential GPS positioning accuracy. We measured the GPS correction data transfer latency via Internet. Furthermore, based on the measured Internet transfer latency, we evaluated of the static positioning results of the Internet-based GPS positioning system.

Satellite communication line is appropriate for network-based RTK-GPS data dissemination to provide wide-area RTK-GPS service. It is possible for network-based RTK-GPS positioning system to provide the precise positions to mass users via the QZSS in Japan. In the other hand, Internet can help construct ground-based differential information distribution and provide various kinds of services corresponding to user's requirements, such as precision request, their link bandwidth, and environment and so on.

(2) An Acquisition Scheme Based on Timing-Synchronized Third Generation Cellular Network for AGPS Receiver

We also proposed an acquisition scheme to provide high-sensitivity and fast positioning service. A function of automatic location identification from an emergency call (E911) is imposed by United States FCC from 2001 and required in Japan from April of this year. These mandates require integrating positioning services in cellular communication networks. Because cell phone carried by people may be at indoors or urban canyon environment where the GPS signal is attenuated and extremely weak, the high-sensitivity for reliable positioning is dispensable. Furthermore, fast positioning response time from emergency call is strictly requested. To improve sensibility and fasten positioning time, AGPS has been proposed. The server with a GPS receiver calculates and sends assistance data to the user. Thus the user can estimate his location based on assistance information and the received GPS signal. Sensitivity during acquisition is critical to a receiver. It is well known that 50 bps navigation data cause a bit polarity transition. That means when a bit transition appears in an integration data interval, processing gain will be decreased. The first problem for a feasible high sensitive AGPS is how to wipe off navigation data. In the signal acquisition process, another problem is that the conventional receiver has to search 1023 chips for each satellite and ±6 kHz Doppler frequency shift and local oscillator uncertainty for a sky search. This process is time-consuming. The second problem is how to narrow the search space to get fast positioning response during signal acquisition.

To wipe off the navigation message, we need the navigation message sequence itself and to align the start time with the received signal bits. The external sub-millisecond time synchronization is essentially needed to find start time. In a 3G cellular network, there are two time synchronization standards: CDMA2000 has 10 microseconds accuracy and TD-SCDMA has 100 nanoseconds accuracy. Thus we suggest wiping off navigation data referring to the precise time provided by timing-synchronized network. During acquisition, there is a two-dimensional search in C/A code and carrier frequency directions. As the start time of 1 ms C/A code is aligned with 20 ms navigation data bit, the knowledge of the navigation data bit start time also helps the C/A code initial phase search. The C/A code search can be performed nearby this start time. To reduce the carrier frequency search range, the conventional receiver store almanac data in memory to perform cold start. From almanac data, we get available satellites information and calculate Doppler frequency shift. However, the old almanac data (for example: several weeks ago) causes frequency error on the order of 10 – 100 Hz. The Computation at receiver is necessary as well. For a cell phone, it is inefficient to store almanac locally because user may not use positioning function frequently, so that almanac data gets old. Another method is to transfer almanac data from the server to the user. But it is time-consuming and will increase communication traffic in cellular network. Thus, we want to predict Doppler frequency shift caused by the motion of satellite at the server and send short information to the user. The user can determine his optimum search space just with simple calculation.

We analyze the proposed system's main errors and evaluate its performance. The simulations proved feasibility and efficiency of our method. The real data received from GPS front-end was used to verify the validation of the scheme. As we assume that the estimated arrival time error of navigation message data is within 20 microseconds, which include time error in timing-synchronized network and user's position error, the processing gain loss in acquisition is so trivial that will not affect the acquisition correlation peak determination. We wiped off navigation data successfully and enabled long-time coherent integration. Thus the sensitivity is finally improved. On the other hand, the C/A code phase can be obtained by searching within only ± 20 code phases instead of searching all 1023 possible code phases, which is 96% reduction of code searching space. This means our AGPS receiver can do hot start in cold start condition. TTFF is reduced as well. In the fast Doppler frequency search method, by analyzing motion of the satellite, earth's rotation, user local oscillator uncertainty and motion of the user, we proposed optimum adjustable frequency search range to different server-user distance. This means a fast cold start. The merits of using our methods for cell phone are as follows: save hardware resource, low computational load and power saving.

To conclude our research, by utilizing various communication networks, firstly, we carried out experiment to try high precision positioning network construction; then we proposed acquisition scheme for AGPS receiver to provide high sensitivity and fast response positioning service. Our proposed systems were evaluated and verified by experiments so that the efficiency and validity of systems are proved. We believe that high performance GPS will bring us more convenient in the future.