Alternatives to Current GPS-RTK Services

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BIOGRAPHIES

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Joël van Cranenbroeck is Belgian and graduated "Géomètre-Expert". After a special degree in advanced mathematics he worked as surveying team leader for control surveys in the Cadastre Administration. In the Geodesy Dept. of IGN he developed data processing and adjustment software, and led special applications development (micro-geodesy, orientation, engineering survey, geodetic network optimisation, inertial and GPS technology). Project leader at Star Informatic then product specialist for GPS, industrial applications, engineering and GIS, and sales and marketing manager for the Leica representative in Belgium. He joined Leica Geosystems AG as Program and Business Development Director for GNSS Network and Structural Monitoring.

ABSTRACT

Many GPS permanent receiver network operators are seeking ways of making their network infrastructure the basis of a profitable business. One approach is to try to recruit a core of users who are prepared to pay for the RTK services. But this is only feasible if the number of users, and the fees charged, are sufficient to generate a reasonable return-on-investment. On the other hand, there are those who advocate that there is no need to recoup investment, that the installed GPS receivers should be seen as public infrastructure such as roads. The topic of this paper is new business models for GPS-RTK services. One concept is a Client-Server based model. What if instead of broadcasting RTK/RTCM corrections and placing the onus of obtaining a final solution on the user and his equipment, the user's coordinates are determined by the service provider? Currently, providers of GPS corrections have no control over the quality of the results computed by users. This makes it difficult for them to justify charging for their services. With the trend towards lower cost GPS equipment, it is clear that putting the computational effort on the server side will justify more easily the charging the users for a value-added product: the user's accurate and quality controlled position in the local reference frame. This paper describes the client-server concept as well as possible business models that may underpin such a service model. These models include some derived from mobile telephony businesses. Furthermore, with the proliferation of independent, competitive RTK services, the concept of a GPS data/service 'broker' is worth exploring.

INTRODUCTION

GPS-RTK network infrastructure owes much to the 'geodesy legacy' of the 1980s. Such networks were established not as businesses, but to support geodetic applications, some international in scope (e.g. to support the IGS and global geodesy), others in support of regional geodynamic studies or crustal motion monitoring. Others still have been established by government land/survey agencies as part of National Geospatial Reference Systems. However, expensive CORS infrastructure is increasingly being scrutinised because of the apparent difficulty in generating a return on this high tech investment. Furthermore, new operators are starting to appear and many would like to understand how to develop a business, perhaps based on new services derived from the GPS data streams. The widespread and easy access to high-speed Internet, and various forms of wireless connection, are now cutting significantly the fixed costs associated with running such infrastructures, and for accessing the GPS real-time data products in the field. The IGS will soon be streaming GPS data from some stations of their global network. New lower cost GPS-RTK receivers and GPS-integrated Total Stations are increasing the number of users. Moreover, the ease of use of such devices by non-survey operators also has the potential to expand the user community for centimeter-level accuracy services.

The topic of this paper is the new business models. One concept is a Client-Server based model. What if instead of broadcasting RTK/RTCM corrections and placing the onus of obtaining a final solution on the user and his equipment, advantage was taken of the existing network infrastructure to compute the user's coordinates in the required reference system? Final (position) solutions for users would be simply computed as a by-product of the continuous network processes – all the time satisfying the quality and integrity criteria implemented at the network administrator level. After all, there exist already a number of web-based services for the generation of coordinates via the post-processing of data submitted by the user.

Currently, providers of GPS corrections have no control over the quality of the results computed by the user. This makes it difficult for them to justify charging for their services. Compounding the problem, providers of GPS hardware typically implement their own proprietary algorithms to compute an RTK-derived position. The approach proposed by the RTCM standards committee will only compound the difficulties by forcing the burden of computational work further onto the rover receiver firmware. Overall this situation leaves RTK service providers in a weakened position to charge for their services, since they do not have any control over the quality of the solutions generated using their data!

A 'client-server' approach alters the data flow in conventional RTK by requiring the field user to transmit their data to a control center. This facility can select the optimal combination of stations to apply network corrections and compute the best possible position before returning the result to the user. Service providers can exercise control over the generated products and, as a consequence, place a commercial value on the service, especially as the user is released from the obligation of learning complicated GPS surveying techniques or software. Safeguards, and thus integrity, can also be easily implemented into the distribution service; if the number of satellites is too low, the geometry unfavorable, or the multipath effects too detrimental, a message can be sent back to the user warning them that the generated solution may not meet their specifications. With the critical concerns of 'legal traceability' and integrity looming, these could be addressed in such a 'reverse RTK' service. An added benefit to this approach is the decreased burden placed on the user receivers by removing the need for field calculations, thus encouraging the development of a new generation of less costly user equipment.

This paper introduces the client-server concept as well as possible business models from mobile telephony that may underpin such a service model. Finally, with the expected proliferation of independent, competitive RTK services, as well as a range of value-added services, the concept of a GPS data/service 'broker' that understands a user's (varying) needs and interfaces with a range of service providers (RTK and others) is explored.

BACKGROUND

It is nowadays recognised that a reference network comprised of permanent stations operating Global Navigation Satellite System (GNSS) receivers operating on a continuous basis provides the fundamental infrastructure required to meet the needs of professional GNSS users in many areas of surveying and mapping. Furthermore, the widespread use of GNSS Real-Time Kinematic (RTK) and Differential GNSS (DGPS) techniques has encouraged geodetic/land/survey government agencies to look for ways to use GNSS reference receivers to support ever expanding non-geodetic, real-time applications of high accuracy positioning for surveying, engineering, machine guidance, precision agriculture, etc. However, it is important to acknowledge that the initial justification for the establishment of CORS networks was to address geodetic applications.

The Global IGS Network & National Infrastructure

The 'super-network' of reference stations of the International GNSS Service (IGS, 2006) exemplifies the global, cooperative, not-for-profit CORS infrastructure that underpins critical geoscientific studies. Hundreds of globally distributed GPS receivers have been operating on a continuous basis for over ten years. Typically IGS stations are many hundreds to perhaps several thousand kilometers apart. Furthermore, the data they have collected have been used in progressive realisations of the geocentric International Terrestrial Reference Frame (ITRF) (ITRF2005, 2006). Many countries have redefined their national datums to be 'compatible' with an ITRF reference frame, by typically linking primary geodetic stations and/or groundmarks to the ITRF via the nearest IGS reference stations. A number of countries have also established 'active' primary/geodetic networks of GPS reference stations to monitor the stability and integrity of their datums. This is particularly the case for countries located on or near tectonic plate boundaries, that cause their datum (or to be more correct, the realisation of their datum in the form of 3D coordinates of groundmarks and reference stations) to undergo deformation with time.

However, the inter-receiver spacing of such networks has rarely been less than a hundred kilometers, and often it is much more. (The exception is Japan's GEONET, with inter-receiver spacing averging about 30kms.) In the 1990s, when the establishment of such CORS networks was justified on geodetic grounds, national networks were similar to IGS stations. That is, although operated on a 24/7 basis, the data was only periodically downloaded from each receiver and transmitted daily to an archive or data center. From there the data was available to users for post-processing to generate coordinates (amongst other products).

Archived Receiver Independent Exchange (RINEX) files from both IGS stations and national GPS reference networks were (and still are) accessed by users via the Internet. All IGS data has been, and continues to be, available at no cost. Although some GPS receiver network operators charge fees for their RINEX files, the trend is to increasingly make such data available for free. If users were: (a) satisfied with post-processed results (i.e. they did not want real-time coordinates), and (b) were fortunate to be carrying out a GPS survey or positioning task 'close' to a reference station, then users could benefit from such data in two ways:

- Download data from the nearest GPS reference station(s), for the time period of their own survey, and then process this data together with their receiver data, using their own software.
- Rather than the user managing all the data files and doing their own data processing, there are several free 'web engines' that can accept data upload by a user, combine it with nearby IGS station data, and carry out the processing for them (examples, AUSPOS, 2006; OPUS, 2006; SCOUT, 2006).

Both modes provide the user with significant savings, as they can obtain high relative accuracy coordinate results without the need to operate their own reference station(s).

Real-Time GPS Networks

With the advent of GPS-RTK techniques in the early 1990s, carrier phase-based GPS technology finally could be seriously considered a surveying tool. Productivity increased to such a degree that private survey companies could invest in the receiver equipment (Lachapelle et al, 2002; Rizos, 2002). At first surveyors operated their own reference stations, and the radio links used to transmit reference receiver data to the user or rover unit. In this way full control was exercised over the positioning system, and the rover unit provided an immediate coordinate for time-critical GPS applications such as engineering construction, detail surveys, precision agriculture, etc. However, to ensure high productivity GPS-RTK (i.e. rapid 'on-the-fly' ambiguity resolution – OTF-AR) there were many constraints, some of which were: (a) that all GPS receivers (reference and rover) must have dual-frequency tracking capability, and (b) the inter-receiver distance should be less than ten or so kilometers. These are significant constraints and the impact has been:

- The GPS-RTK system was the most expensive of all GPS technologies.
- Reference receivers were set up on an ad hoc basis, only for the duration of the survey.
- Proprietary formats and protocols proliferated.
- Communication links were point-to-point, not broadcast (in contrast to DGPS services).
- No sharing of reference receiver data with other users was possible.

The most serious implication was that it was difficult for any agency or private organisation to justify the establishment of a network of GPS reference stations with inter-receiver spacing of the order of 20km covering an entire region (so that reference-rover distances could be kept to under ten kms in order to ensure rapid OTF-AR).

This mode of 'single-base' RTK was soon supplemented, from the late-1990s, by the so-called 'network-RTK' approach, where the spatially correlated atmospheric and satellite errors (orbit and clock) could be better mitigated using *several* GPS reference stations surrounding the rover receiver. However, the greatest impact on GPS receiver infrastructure was that network-based techniques enabled cm-accuracy positioning with reference receiver spacing of between 50-100kms, even in real-time (Rizos & Han, 2003). As a result of this less-dense reference station spacing, by the late 1990s and early 2000s many government and private network operators became interested in the economics of network-RTK. Furthermore, in this new era of real-time data streaming, the number of reference stations contributing GPS data over the Internet grows daily. The IGS, and some national geodetic GPS reference stations, will soon provide their data streams for free. On the other hand there may be some government and private GPS networks that will continue to charge fees. The 'marketplace' for GPS data will therefore become increasingly confusing.

COMMERCIALISING GPS-RTK NETWORKS & SERVICES

Organisations that are currently providing free real-time data streams typically justify the costs of implementing CORS networks by citing the approach of 'preventable costs', similar to the strategy used to finance the establishment of classical geodetic networks decades earlier. The return on the original investment is not measured in terms of revenue earned, but justified as a means of keeping the costs borne by the local geospatial industry lower than the alternative (i.e., having no geodetic infrastructure). This approach also has the advantage of encouraging network standardisation and avoids the establishment of a patchwork of private, ad hoc networks for project-specific purposes.

If extended to real-time operations the net result of these free - but limited - services (they may only support single-base RTK 'out of the receiver') would be to give the user the impression that the distribution of GPS-RTK corrections should remain free of charge, and that the cost of establishing and maintaining the networks, and providing services, should be borne by the network operators. In fact many agencies are currently facing an uphill battle in trying to convince potential users to subscribe to their real-time GPS services. The primary reason is the disproportionate cost for the offered services when borne by a limited number of customers, typically the land surveyors who require high accuracy positioning on a day-to-day basis.

Business Cases Based on Mobile Telephony

There are business models based on mobile telephony that could be investigated. The costs of cellphone handsets are largely subsidised by the telecommunications service providers because they generate revenue from the customer services, not from handset sales. What lessons are there for next generation GNSS-RTK service providers who also want to become profitable? Consider two models for permanent GNSS reference stations based on some form of subsidy for the establishment of GNSS-RTK reference station infrastructure:

- To drive an increase in the sales of user receivers, generally supported by very low service fees. *This scenario would be best if the aim is to market high-value dual-(or triple-)frequency GNSS receivers.*
- To drive an increase in revenue from service fees, generally encouraged by very low (even free) user receiver hardware. *This would be the preferred scenario if the rover hardware were of the low-cost variety, such as current single-frequency systems*.

The former may be favored by GPS manufacturers, who could be expected to perhaps even establish CORS networks where ones do not exist, so as to encourage the sale of expensive user equipment. The latter would be favored by GNSS-RTK service providers, but there would be little interest by GPS manufacturers of high-end user equipment.

Business Cases Based on Notions of Quality Assurance

What if service providers wish to control or/and tailor the quality of services based on the type of products their networks provide? They may also committed to providing GNSS network solutions in the appropriate reference system (local or national datum), as often the very justification of permanent GNSS networks by the national geodetic agency was in order to offer a complete, integrated, datum-consistent solution that may include geoid height correction.

Some argue that any datum transformation algorithms that may be required could be integrated into the user receivers, and that a certain level of control can be achieved by forcing the user to calibrate their system on existing control points. This is exactly the situation with the decision last year by Omnistar to provide only correction data that ensures coordinate results are obtained in the ITRF datum, not in a locally-realised geocentric datum. For example, the Geocentric Datum of Australia (GDA94, 2006) was 'frozen' to ITRF92 at epoch 1994, and since that time the tectonic plate motion of the Australian continent has resulted in the divergence between the GDA94 and WGS84/ITRF2005 datums (and the groundmark or permanent GPS station coordinates that realise these frames) to grow to almost one meter!

The subject of increased data integrity is also creating considerable interest among GNSS network operators and/or service providers. What if they could provide a service that overcame the problems that users routinely encounter in processing their own data? A reliable GNSS-RTK service providing high quality solutions could generate significant revenue because of the 'value-added' nature of such high integrity services. In fact, many current GNSS-RTK network operators may not appropriately charge for their data/services because they cannot guarantee continuous and reliable positioning!

TOWARD NEW MODELS FOR GNSS-RTK SERVICES

Client-Server Model

What if, instead of broadcasting corrections or data and placing the onus of obtaining a final solution on users, advantage is taken of the existing GPS network infrastructure to compute their coordinates in the required reference system? Final (position) solutions for all logged users could be simply computed as a by-product of the continuous network processes – all the time satisfying the quality and integrity criteria implemented at the network administrator level. After all, there exist already a number of web-based services for the generation of coordinates via the post-processing of data submitted by the user Therefore one business model would extend this capability to real-time processing. Currently, providers of GNSS corrections have no control over the quality of the results computed by the user and, as already suggested, this makes it difficult for them to justify charging for their services.

A 'client-server' approach reverses the data flow in conventional RTK by requiring the user/rover to transmit their data to a control center – sometimes also referred to as *reverse RTK* (see Figure 1). This facility can select the optimal combination of stations to, for example, apply network corrections, and compute the best possible position solution before returning the result to the user. The advantages of such an approach are clearly evident. Service providers can exercise control over the generated products and, as a result, place a commercial value on the service.

In addition, the user does not have to learn complicated GNSS surveying techniques or software. Safeguards, and thus integrity, can also be easily implemented into such a service. For example, if the number of satellites is too low, the geometry is unfavorable, or the multipath effects too high, a message can be sent to the user warning them that the generated solution is not optimal and that it may not meet their specifications. With legal traceability and integrity requirements becoming more important, such 'total quality assured coordinate services' look increasingly attractive.

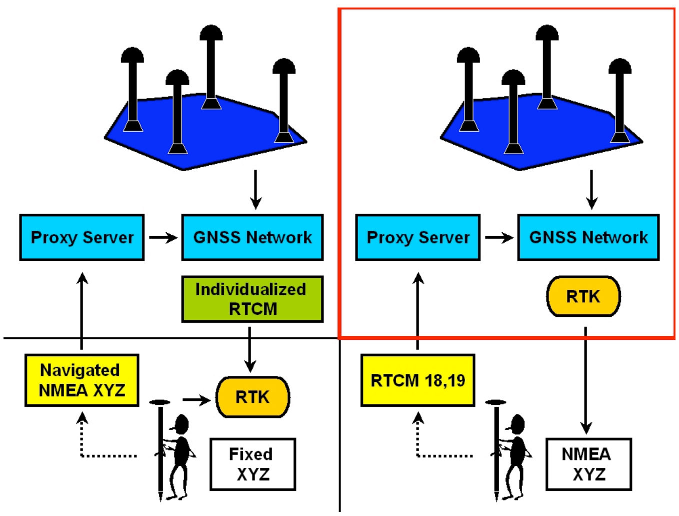

Fig. 1 Standard GNSS-RTK (left), reverse (client-server) GNSS-RTK (right).

Furthermore the computing facility can derive easily the local coordinates, even corrected using a geoid model. A more sophisticated approach can therefore be implemented for transformations (horizontal or vertical) using, e.g., grid corrections, and updated at any time. See Figure 2. An added benefit to this approach is the decreased burden placed on the rover units by removing the need for field calculations, thus encouraging the development of a new generation of less expensive user hardware operating only in a network context (similar to one of the mobile telepony business models). Another value-added service would be a variation of assisted-GPS (A-GPS), a network-based technique used to perform positioning under weak signal conditions (as in the case of GPS-equipped cellphones being used indoors or under trees). The receiver coordinate would be computed at the control center, and sent to the user.

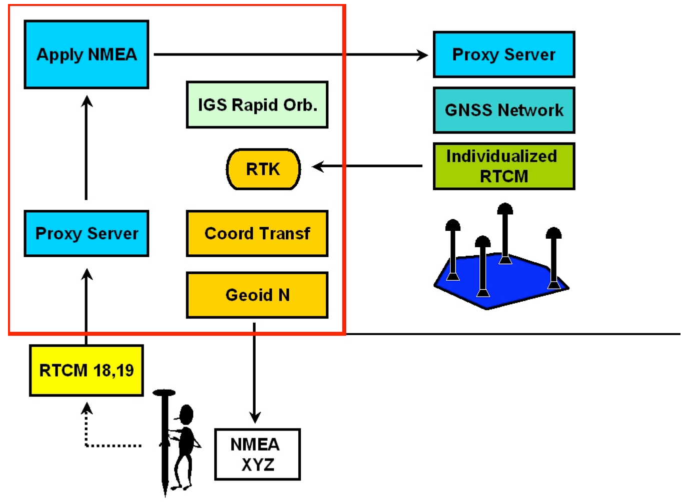

Fig. 2 Sophisticated client-server GNSS-RTK model implementing transformations.

The GNSS-RTK Service Broker

In fact the client-Server approach doesn't need to be implemented in an existing GNSS-RTK Network software solution. It can be independent. Examples are the SmartNet implementation in the U.K. where Leica Geosystems is gets the raw data from the Ordinance Survey network and processes independently of other RTK services the raw data to derive new products such as MAX and I-MAX. Nippon GPS Solution in Japan is doing the same using data from the GEONET network. For example a *service broker* could check which GNSS-RTK services are available in the vicinity of the user and then arrange for the user's position to be computed by accessing one (or more) service provider's or network operator's VRS, FKP or I-MAX data stream. The user's position could be computed using different models and then a 'majority voting' process applied to deliver a more reliable solution (Figure 3). In some cases there may not be a network-RTK service available, then a DGPS solution can be provided based on a sparse network of stations; perhaps a free marine beacon-based service or even a fee service such as Omnistar's.

Furthermore, there may be several, independently operating CORS networks, each offering a similar service (Figure 4). The user could access the cheapest ('best deal') or a 'multi-network' solution. In addition, services other than just conventional RTK could be offered, such as time series analysis, tracking/monitoring of user receivers (e.g. if the field survey is for structural monitoring), and so on. The task of the data/service 'broker' would be to act as the agent for the user, interfacing with the various service providers (RTK and others), ensuring that the user's requirements are met. Such a GNSS-RTK service broker would establish commercial agreements with existing GNSS network service providers, much like the telecommunications operators today enable cellphone 'roaming'.

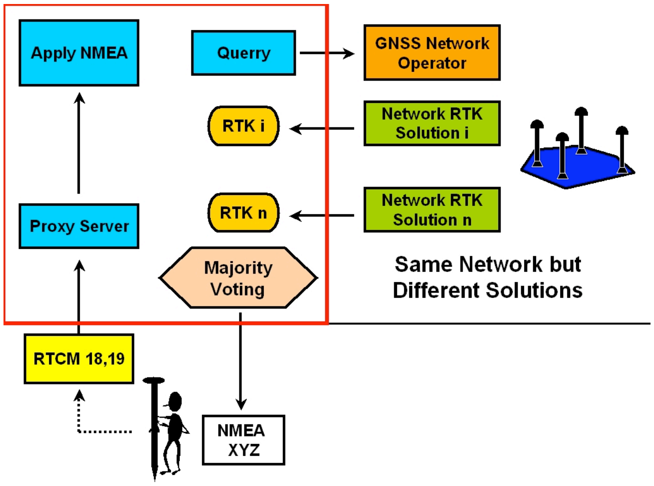

Fig. 3 GNSS service broker accessing different RTCM/RTK services.

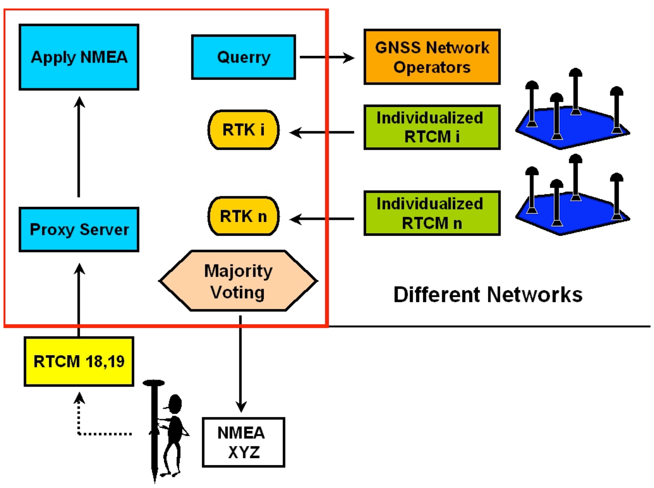

Fig. 4 GNSS service broker accessing different networks.

Case Study 1

Let's imagine that a surveyor is arriving in a country to conduct a survey. When he/she lands at the airport he/she will power up the GNSS equipment and will 'log onto' his/her service broker. The surveyor knows that some networks have been setup in the vicinity. He/she will select the accuracy needed to travel to the area where he will have to organise his survey. The accuracy needed is few meters, and he/she will automatically be charged for the DGPS service. When the surveyor arrives at the site, he/she will change his /heraccuracy criteria to (say) 5cm with a confidence level of 99%, and select the local datum in which the coordinates are wanted. When the surveyor leaves the site with all the points coordinated he/she will terminate the 'transaction'. Automatically all the coordinate information (and perhaps point attributes) he/she has collected will be forwarded immediately to the office via his/her service broker.

Case Study 2

Some drivers that have crossed a bridge have noticed some unusual movements and have raised the alarm to the Highway Authority. Immediately a set of GNSS receivers are placed at critical locations and commence operating. The premium 'mission critical' service with best accuracy and reliability is selected by the service broker. Automatically these receivers are identified and located by the appropriate network/service provider and their positions computed in real-time, and perhaps smoothed with a sliding window post-processing solution as well, and the results forwarded to an analysis center that is responsible for the frequency domain analysis (another value-added service). The coordinates have been transformed into the local bridge axis system for better visualisation at the headquarters of the highway authority.

CONCLUDING REMARKS

The following summary comments can be made:

- Permanent GPS networks are a 'geodetic legacy' that has been established over the last decade or so. However these were not initially intended to support real-time positioning applications.
- With the development of RTK techniques (single-base or network-based), cm-level GPS positioning became a useful surveying/mapping tool. Applications in non-traditional applications are increasing.
- At first specialist users established their own reference station(s), but over time real-time services were offered by the GNSS receiver network operators. However, most of these services are not operated on a sustainable business basis.
- New business models are needed if service providers are to generate the revenue necessary for infrastructure maintenance and upgrade. Some may involve subsidising the network infrastructure to sell more user hardware. Others may involve subsidising the user equipment with a view to 'selling' more RTK services.
- One set of models are based on the client-server architecture, where the client (the roving user) streams raw GNSS data back to a server (a computing center), where the coordinate computation is carried out. The client pays for a reliable service.
- Variations of this basic model can be developed by studying how mobile telephony business is conducted. For example using data/service 'brokers'.
- The concept of a service broker is an innovative new model for supporting a range of value-added services, not only 'standard' GNSS-RTK.

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