Multipurpose Nation-wide Real-Time Reference Station Network - From Geodetic Control to Precise Positioning and Much More…

Pierre DESJARDINS, USA

Key words: RTN infrastructure evolution- added accuracy scalability and new market segments

SUMMARY

Reflecting on past experience and evolution of Real-Time Network (RTN) technology and vertical user markets, one clearly sees a dramatic shift in the adoption rate within the geodetic community quickly expanding both geographically and across new customers.

While the “western world” adoption of RTN is fait accompli, barrier to entry remains high in the Emerging Economies around the world, based on many factors – namely absence of modern communication infrastructure, technology adoption status & experience, initial & operating cost of RTN and a relatively small market audience who has other higher social priorities to tackle.

A new 3rd generation RTN solution is now coming to market to enable more simultaneous users and applications across a broader community of users, so as to increase adoption rate in all regions, but specifically for the Emerging Economies markets.

SOMMAIRE

À l'échelle mondiale, les Réseaux Permanents à temps réel (RTN) et ses marchés desservis nous révèle un haut taux d’adoption auprès de la communauté géodésique à prime abord, qui éventuellement se propage au cours des dernières années à des tous nouveaux types d’utilisateurs, ainsi qu’à tout les continents.

Malgré l’adoption rapide du RTN par les pays développés, ce n’est pas le cas pour les pays en voie de développement et de multiples facteurs y contribuent, notamment : absence d’infrastructures locales & nationales (énergie & communication), adoption et l’expérience des technologies de pointe reliées au RTN en balbutiement, les coûts liés à l’implantation et la maintenance du RTN, et la taille du marché des utilisateurs potentiels – lorsque comparé avec les besoins prioritaires de ces sociétés.

Une nouvelle (3ième) génération de solution RTN est lancée permettant plus d’utilisateurs concurrents – tant au niveau de la variable “précision”, et/ou lié au nombre d’applications

nouvelles allant chercher de tous nouveaux utilisateurs. Résultat: une adoption encore plus rapide de la 9^{ième} « utilité publique », surtout pour les pays en voie de développement.

Multipurpose Nation-wide Real-Time Reference Station Network - From Geodetic Control to Precise Positioning and Much More…

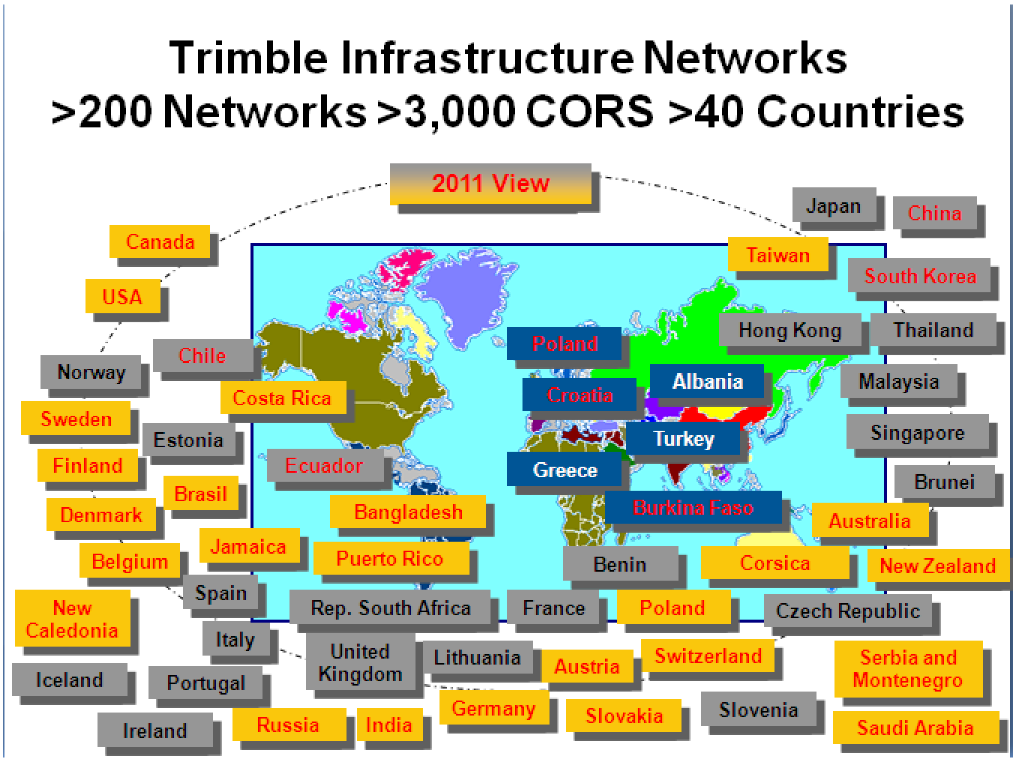
Pierre DESJARDINS, USA

1. FROM THE RECENT PAST

The emergence of Real-Time Network (RTN) technology has a very young history on just about any (technology) scale, as its first adopters came from Germany in the late nineties; also the birthplace of the RTN technology. Its adoption within the modern western European geodetic community was quick as the cost savings it allowed as compared to establishing & (mostly) maintaining the 1st, 2nd or 3rd order geodetic network were obvious. And traceability of the results as well as the ability to apply local coordinate and correct for single or multiple tectonic distortion was unheard of before.

Often referred to as "VRS System" - an acronym of the "Virtual Reference Station" technology popularized from the very beginning by Trimble, and for which the "Trimble VRS^{TM} technology is a specific branded solution of the virtual reference station concept.

With the RTCM sc104 adoption of the non-physical reference station solutions under the RTCM 3.1 standards, the use of RTNs has grown exponentially, and today, most of the western world has one or more overlapping RTNs operated by either private or public organizations.



RTN got a few lucky breaks along the way which explain its proliferation around the world:

- Simultaneous advance in the micro-computing technology brought the 32-bit computer power at a very aggressive price point while software development tools made it easier to develop large and complex solutions such as RTN
- A better understanding of both the upper (ionosphere or TROPO) and the lower (troposphere or IONO) atmosphere lead to the development and implementation of a variety of standardized atmospheric models to further alleviate the atmospheric degradation of the GPS (and GNSS) signals as it penetrates its layers. So not only was the foundation of the non-physical (or virtual) reference network solutions created to reduce the number of physical base stations and improve customer efficiency for GPS/GNSS field measurement, the science itself benefited from on-going research to further improve its solutions.
- As one would have it, the 13-year solar cycle was relatively calm until only a few months ago, and allowed ideal conditions to develop and implement improved solutions.
- Increased interest by the society to improve the regional & national weather forecasting – for sport, construction, agriculture and tourism – lead to precise "nowcasting" solutions derived from GPS observations on the TROPO region of the atmosphere.

2. THE SECOND GENERATION

Once the early adopters – Western Europe centered around Germany, followed by Japan – demonstrated their success to the world, the science experiment definitely switch to the (relative) mass community of geodetic users – not that these is a massive number of such animal around the world – but it became the *de facto* standard whenever a region, a province or a country needed to implement a coordinate reference backbone network or even when an existing conventional network of concrete and brass plugs needed to be re-observed…again. The new RTN technology was an automatic modernization solution, and in most cases, it became more tedious to try to maintain the old "brass plugs-and-concrete monument" coordinate system than to simply use a RTN approach. Today, many organizations are still spending large budget to re-observe the old network from the new RTN, to integrate the old structures into the new world…something the new RTN never have to deal with.

The end of the 2nd generation has started to realize that the ultimate absolute reference system is that of the earth GPS/GNSS coordinate reference system (ITRF) which is established by the constant observation of its position from one or more constellation of orbiting satellites (GPS, GLONASS, etc.).

And in case you asked, yes, these constellations are also themselves "calibrated" constantly and in quasi real-time by another set of tool an order more precise than the constellation itself: VLBI (Very Long Baseline Interferometry) measurements from multiple and simultaneous locations on earth of distant celestial objects (Quasars) to determine minute variation of the earth's rotation orbit parameters. (This is how a 10 cm shift in the earth rotation axis was detected after the major Japan earthquake of March 2011.)

The 2nd generation of RTN is therefore well accepted by the geodetic community given all these refinement in the peripheral sciences supporting the GNSS constellations from which it is all possible. Besides the RTCM standards established jointly by all major GNSS manufacturers to ensure the customer receives the same experience globally, other international organizations such as IGS are making sure the norms are maintained as it refers to accuracy. Only accuracy?

3. EVOLUTION POST WESTERN WORLD

From its original foundation deep in Germany, the justifications by any regional, state or national institution to adopt an RTN was primarily governed by maintaining – and in some cases establishing – the common ubiquitous reference backbone to allow a "coordinated" approach to land development, and more particularly for cadastral development.

Others had – and continue to have - even bigger visions and ambitions, and most of the

~90 RTNs deployed today in China are a mean to an end called the "Digital City → the Digital Province → the Digital Country. This type of vision can only be realized if one has a sizeable budget to justify it, and not every country can boast to have such a large trade surplus to finance its "Digital Country" development.

Besides China, if one looks at *other* developing countries, one quickly realizes the massive issues faced by these emerging economies to adapt this "Made in Bavaria" solution overnight. Despite the implementation of global standards, the advent of high power computers at low prices – as predicted by the Moore's law, and therefore expected to continue for at least another decade – most of these regions simply do not have the required electrical grid and/or a reliable grid to ensure a reliable SLA for this basic commodity. And this is only the most basic requirement to implement Bavaria in Western Africa or in Haiti! The most striking technological evolution that boasted the rapid outreach of the 2nd generation RTN in all new geographies was heavily correlated to the rapid growth of the Internet in these same geographies. ADSL based data communication for LAN quickly replaced the very expensive ISDN-based solution, at a fraction of its cost. Cell phone appeared everywhere and most regions are gridded with cell phone towers.

Again, the 2nd generation RTN has many lucky breaks in the western world. But these required infrastructure component are essential to all RTN and become major barrier to entry. Then, the combined knowledge and experience required of a RTN operator is not easily found in most universities even in Europe. So how can we overcome this obstacle to RTN – a recognized structure component of any modern social development where land reform and cadastre is implemented to implement the price of land ownership?

4. THE 3RD GENERATION SOLUTION: MORE ACCURACY-BASED USERS AND MORE APPLICATION BASED USERS = MORE USERS^2

The very origin of the RTN technology/solution may be to blame as it relates to its limited scalable flexibility to adapt to various users needs as it relates to accuracy. But then again, Germany develop the best and most accurate (*German Engineering*) solution it could think of and pushed the envelope several times faster than any prior generation had done in the field of modern geodesy.
But a cm^2 of land in Munich is exponentially more valuable than the same cm^2 in Western Africa or many other regions of the developing economies of the globe, and the end user would be more than satisfied by a rough sub-meter accuracy, particularly if at the same time, the solution implemented can be – at a later date and seamlessly – regionally and incrementally scaled up to the higher accuracy, as the need arises and the economy permits.

The 3rd Generation RTN technology does exactly that – not only from an accuracy POV, but also by allowing a greater number of users to share the same platform, thus decreasing the per-user cost footprint.

Accuracy:
Recent advances in the development of yet another order of computer performance based on 64-bit distributed architecture on the ".net" protocol have enabled the full use of the new multi-core computer servers.

In turn, a better understanding of the IONO modeling and more exhaustive mathematical model have been developed supported by this technology, which can now provide a more flexible and scalable "accuracy" solution.

Whereas in the past, only higher cm-level accuracy were possible under the RTK technique, one can now provide different accuracy RTK-based solution as a function of the interstation spacing of the network, the local IONO gradient, the type of RTK solution running in the rover, and of course, the 2 basic conditions remain: Reliable electrical supply and low-latency LAN and wireless communication for the interconnectivity of the CORS with the Computer Center (CC) and for the ability of the rovers to wirelessly reach the computed corrections at the CC via a NTRIP connection.
It is now possible to compute and provide a consistent 10-cm (horizontal) position via a Sparse VRS™ network where the distance between the CORS can be anywhere from 100 to 300 Km. The distance between the CORS stations is directly proportional to the local IONO activities, and indeed the IONO conditions in the equatorial band where most developing economies are located is the worse anywhere in the world. So the maximum distance of 300Km will likely never be possible.

The interstation spacing can be derived empirically and as the ionospheric conditions worsen until the solar max of May 2013, one must be careful to plan the grid accordingly.

The relationship between the cost of an RTN and the distance between the stations is not proportional – it is an exponential relationship. Going from 50 Km to 100 Km means only ¼ of the CORS are now required.

This mathematics fits extremely well with one of the limiting criteria of RTN adoption in the developing economies: access to capital funding! Trimble Sparse VRS™ technology allows a scalable entry to the RTN world.

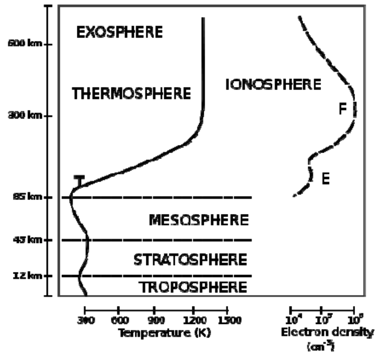
New Applications:

Ever since the beginning of the RTN development, the focus has been to serve the geodesists, and to replace conventional national geodetic networks with a real-time solution to serve essentially one class of users: The surveyors.

Nothing wrong with that, provided the community of users can afford both the initial technology and its on-going maintenance. A first glance at adding application came at the end of the 2nd generation with the implementation of precise Integrity Monitoring (Trimble Integrity Monitoring™) for network administrators. This tool – again based on high-accuracy positioning – was even more accurate and acted as a mean to monitor and detect in booth real-time or in post-processed mode any minute variation in coordinates of the CORS location – independent of their spatial positional shift happening over seconds or over long period of times (months).
This application lead to offering GNSS-based Deformation monitoring based on RTN; a tool particularly appreciated for large and very large object – from a large bridge, a water dam, a valley's subsidence or even the drift of a continent.

So RTN had made the first step towards reaching additional users besides the surveyor community? But why should this technology that provides ubiquitous cm coverage be limited to Surveyors only? Is it because the solution targets the cm-level high-accuracy only?
As we saw above, new RTK techniques developed under Sparse VRS™ solution allows an extension to the accuracy that these networks can provide. So a different community of users with lower accuracy requirement can now be addressed. In particular, the MGIS community for asset management is a logical one.

But this is still in the same direction. Why not push the envelope in a different direction? Rather than to resolve the atmospheric disturbances of the IONO & the TROPO layers, why not instead look for application dealing with the disturbances themselves?



For this process, the Trimble ATMOSPHERE application was developed.

It uses the same ground CORS infrastructure, augmented by MET sensors connected to the CORS to measure the GPS signal delay created by the TROPO layer (up to 10KM) and computes precise IPWV (Integrated Precipitable Water Vapor) as often as every 15 seconds. The precise determination of the amount of water vapors at different altitudes within the troposphere is used to refine weather model, and provide quasi-real time weather forecast or "nowcasting".
And now, a brand new group – and often much larger than the surveyor community – is involved in the desire to establish a RTN in their community.

Actually, it is our belief that for many developing counties, the need to have more predictable weather prediction will be the first enabler or justification for the deployment of these national networks, but the very fact that these various users are now sharing the same RTN infrastructure is the most important design element of the solution. Once a basic - sparse or not – network is deployed for one community, it becomes the anchor for the next community who can easily leverage and augment on the work already done by another community of users.
Just think: How many more user community could benefit of this common infrastructure? We have only started the 3rd generation of RTN with Trimble VRS3Net. It is the enabler for a much larger community of user. Many more APPs will be added to the basic platform. The two examples stated above are but the start.
And ultimately, it is the best way to eliminate barrier to entry for the Developing Economies of the world: Having a common infrastructure RTN shared amongst multiple users and communities.

CONTACT

Pierre Desjardins
Trimble Navigation Ltd.
10355 Westmoor Drive
Westminster, CO
USA 80021
Tel. +1 720 587 4470
Fax + 720 293 9830
Email: Pierre.DSesjardins@Trimble.com
Web site: ww.Trimble.com