GPS, Galileo and the Future of High Precision Services: An Interoperability Point of View

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Abstract. Modernised GPS and Galileo are going to provide, standalone or through code augmentation systems, meter level accuracy. Such accuracy is commonly considered sufficient for the most of the applications. Nevertheless, other higher accuracy applications like Geodesy, Cadastral Surveying, Mapping, Marine surveying, etc. are still stable niche markets. New applications, as High Precision Cartography and ADAS, are emerging. As in any business, the more the offered service precision will be, the more the precision requirements improve. Centimeters level high accuracy is currently achieved through GPS Reference Stations Networks and the integration of mobile terrestrial or satellite communication systems for corrections broadcasting. The weakness of such systems, in RTK mode, are very well known: low density Reference Stations networks coverage for large areas, not homogeneous performances, not reliable communication systems coverage, not guaranteed reliability of the positioning, complex positioning and communication integrated devices, absence of a comprehensive Business Model.

A regional Network backbone design in terms of Reference Stations distribution and separation is needed, integrating existing subnetworks developed for Geodesy, Land Surveying, University research, Marine applications, etc . . . Network spacing is highly dependent on spatial-correlated errors, but MRS/VRS and innovative WARTK approaches, together with three-frequencies availability and TCAR algorithms, will allow to get real instantaneous and homogeneous solutions at large scale. Tight integration with Communication systems is essential for delivering a reliable Real-Time service. Availability of higher mobile communications (e.g. WIMAX) is opening new doors for that. Furthermore, the future availability of a standardised backbone of Galileo Local Elements will provide a great impulse to such integration. Galileo is also studying Business Models for such Services, starting from the availability of innovative services (e.g. Service Guarantee and SoL).

An analysis about GNSS High precision services perspective and interoperability has been performed from different applications points of view, including Galileo future services.

1 State of the Art of High Precision Systems and Services

Satellite geodesy and surveying applications were the first developed since the beginning of GPS operability. The use of carrier phase measurements instead of pure C/A code pseudorange suddenly showed a great potential for getting baselines among receivers with centimetric level accuracy. The cost of using phase measurements was anyway high. The necessity to solve initial phase ambiguities for using phase measurements implies: 1) the need of a fixed Base GPS Station located in the neighbours of the rover; 2) the need for rover receiver phase measurements and ambiguity resolution processing; 3) the need of a robust, relatively low latency communication link between the rover and the Base Station for RTK corrections/ raw data transmission. RTK is by far the main objective of this paper. The first problem has been solved initially trough the use of a couple of receivers on the field, while networks of GPS Reference Stations have been developed by Geodetic institutions, Land Surveying Authorities, Mapping Authorities, Coast Guards, etc. The basic limitation of GPS Networks development was (and it still now is) due to the Reference Stations spacing. RTK solutions are still constrained for ambiguity resolution by distance correlated errors (e.g. ionosphere errors), limiting the rover to Reference Stations separation to 15–30 Km for a good percentage of correct fixing. This implies the development of very dense Networks for a uniform High Precision Service over an entire Country. Concerning ambiguity resolution techniques, many core algorithms have been developed and are today integrated within all code/phase receivers (e.g. LAMBDA and FASF).

Communication link availability has been for years another limiting factor for RTK positioning. VHF/UHF transmitters and receivers at Base Station and rover side were firstly adopted by surveyors, but several limitations are present due to RF licensing and link robustness. Since ‘90s, the use of mass market mobile communication technology favoured an expansion of GSM and GPRS based RTK systems. Also in this case the corrections transmission costs and links robustness are limiting a full exploitation of such services.

In last ten years, some of those problems have been tackled through the development of Network-RTK technologies (i.e. MRS/VRS approaches). Instead of using a Single-Reference Station approach, a set of Reference Station in the neighbours of the rover is used for modelling and estimating distance-dependent errors. Such an approach allows significantly increasing the Reference Stations separation in the order of 100 Km. In such a way, the number of Reference Stations and relevant cost for developing a nation-wide High precision system can be significantly reduced. Those approaches also lead to an improvement in correction transmission modes, from the generation of a VRS (Virtual Reference Station) close to the rover and relevant RTCM messages sending, to a pure broadcasting of interpolation parameters for errors estimation valid in an entire area surrounded by Reference Stations. The advent of TCP/IP and packet communication leaded recently to the development on IP-based corrections broadcasting protocols, paving the way vs. a real exploitation of this market. Precise Stations Coordinates updates and robust Communication links are also here the requirement.

Another limiting factor is the cost of receivers. It is anyway expected that the future availability of High Precision Services (HPS) and new satellite systems will generate an economy of scale for high precision receivers markets.

On the other hand, satellite augmentation systems (WAAS, EGNOS and MSAS) are currently able to provide meter level accuracy and relevant integrity services for code measurements.

The availability of future GNSS third frequencies leaded to the development of new algorithms for Ambiguity Resolution (TCAR). Anyway, future GNSS constellations and relevant third frequencies cannot improve at great extent ionospheric errors estimation. Reference Stations Networks will always be needed ([5]) for RTK.

TCAR, integrated with innovative WARTK (Wide Area RTK) algorithms, will allow real instantaneous centimetric solutions using long baselines Reference Stations networks.

The future challenge of phase measurement is therefore the development of uniform coverage, sub-centimetric accuracy services in real-time with a high level of reliability and reduced costs for infrastructures. Galileo Local Elements design and relevant development of a Regional Network is an opportunity for Europe for having a real full coverage high precision service to be used for traditional (Mapping, Surveying) and innovative applications (ADAS, Road Lane Keeping, High Precision mapping). The development of dedicated Business models for that is one of the most relevant tasks.

2 Current GNSS Networks Coverage and Integration Perspectives

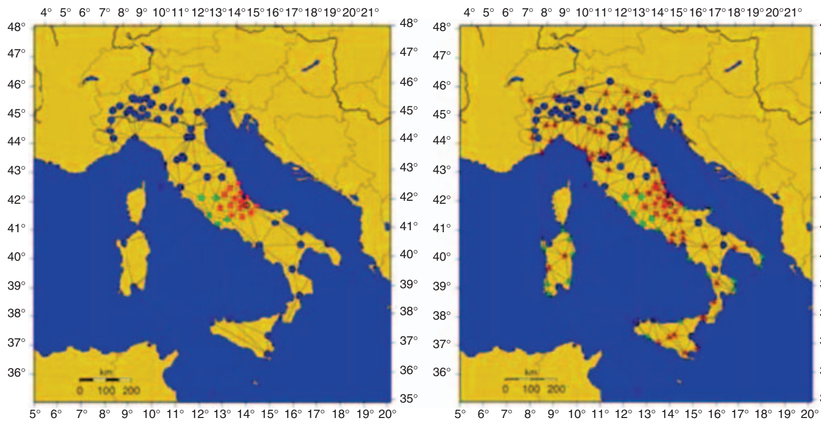
Current development status of Reference Stations Networks and High Precision Services in the world is very variegated.

Apart from basic regional Geodetic Reference Stations networks, like IGS and EUREF, developed for Reference Frames determination/update, the major part of each Country developed their own Reference Stations for National datum realisation. Such Reference Stations, due to their specific objectives, are commonly wide spaced and not equipped for real-time applications.

In some countries, Mapping or Cadastral Authorities developed national or local networks for RTK applications. In some cases such networks are providing a Post-Processing or Real-Time service for all the Country based on MRS/VRS. This is the case of GPSnet.dk, composed by 26 Stations, providing a VRS service all over Denmark, or of the SAPOS Network, composed by about 300 Stations, providing MRS/VRS services for the whole Germany.

In other Countries the situation is much more fragmented. Local sub-networks based on a single-station RTK or MRS/VRS approach have been developed by Local authorities, Surveyors Organisations, Universities, etc., and are providing Local High Precision Services. In most of the cases such initiatives are in prototyping or test phases and cannot guarantee the required service levels.

An example of such situation is Italy. In the following left picture, Reference Stations currently operating or starting to be operating are reported. As can be seen, while North-West and Centre of Italy are quite well covered, other Italian areas (e.g. coastal regions) are not. In that scenario, it is not cost effective to re-build ex-novo an entire optimum shaped network (less than 100 Reference Stations should be necessary to complete the Country coverage). The re-use as much as possible of existing infrastructures (e.g. Communication networks and available Reference Stations) and the eventual densification with new Reference Stations should be opportune. Taking into account the fact that not all the areas of a Country need the same level of coverage (e.g. mountains regions could be less covered by a Real-Time service), a densification of the network has been studied. In the following right picture, a densification using existing Public Administration sites (triangles) and new Coastal Reference Stations (stars) installation is showed. The total number of stations in this scenario is expected to be in the order of 150.



Summarizing, three basic Coverage Scenarios can be found:

Scenario 1: Countries poorly covered by network of Reference Stations or needing a reliable structure for institutional purposes (e.g. Cadastre development in European Eastern Countries); this is the case for the development of a new network of Reference Stations based on Network-RTK

Scenario 2: Countries already partially covered by Reference Stations Networks developed by several entities; integration of different networks and reuse of existing infrastructures under an Institutional umbrella is here the preferred solution

Scenario 3: Countries fully covered by an advanced Reference Stations Network; in this case, the only requirement is the *Open approach* versus future Regional systems, through the use of standard interfaces versus a Regional Control Centre for real-time raw data and ephemeris transmission.

3 Network RTK Technology

Network-RTK concept was developed for overcoming limitations of single-station technologies to provide High Precision Services over a wide area. Such limitations are due to distance-dependent biases (ionosphere and troposphere refraction, orbit errors). Those errors can be accurately modelled using a set of Reference Stations surrounding the rover instead of a single station. This is the basic idea of Network-RTK approach. Basic Network-RTK steps are the following:

1) *Network ambiguity fixing*: ambiguities among Reference Stations receivers are calculated. Only fixed–ambiguities carrier phase measurements can be used for precise errors modelling. This ambiguity fixing method differs from the rover ones due to the fact that precise Stations coordinates are known.
2) *Corrections estimation*: errors corrections are here estimated. Different methods have been developed for modelling errors corrections parameters. Methods working on differenced or undifferenced observables can be distinguished. Differenced

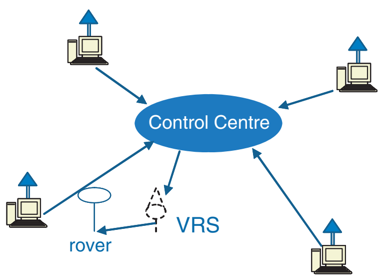
methods estimate errors through statistical modelling of differenced observations, while the undifferenced ones operate on direct observables, through estimation of observations corrections in the State Space domain through dynamic modelling and Kalman filtering.

One example of Differenced method is provided by the analysis of the errors through the collocation method ([1]). In such case the measurements Covariance Matrix is modelled in order to estimate the correlation between errors. Distance dependent errors (orbit errors, ionosphere errors and troposphere errors) are distinguished by uncorrelated errors (receivers clocks, Phase Center Variations-PCV, multipath). A relevant effort has to be put in modelling Covariance and Cross-Covariance matrixes through mapping functions depending on satellite elevations and distance.

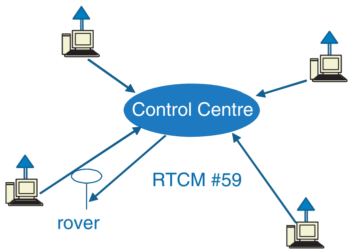
Concerning the Undifferenced approach, one of the most common ones is reported in [2]. In this case, all single measurements errors are dynamically estimated though a Kalman filter working in the State Space.

In Network-RTK, reliable Ambiguities solutions require very precise Reference Stations coordinates. PCV derived by antennas calibration are therefore needed.

3) *Corrections transmission*: transmission of corrections can be performed in two basic ways.
   - VRS: the rover sends its approximate position to the Control Centre through an NMEA message; the Control Centre calculates corrections and, starting from a selected Master Reference Station, relevant observations are shifted close to the user in a VRS; raw data or corrections for the new station are sent to the user through RTCM messages (#18 and #19 or #20 and #21). The limitation of such mode is the need for a bi-directional communication link between the rover and the Control Centre. Alternatively, a grid of VRS corrections can be sent to the user, leaving to the rover the VRS selection. A Cluster for providing such service is composed of a minimum 3 Reference Stations (up to 8, depending on computation load on a single server)



   - Surface corrections parameters: errors are described as a polynomial function (e.g. FKP, [2]) all over the area covered by the Reference Stations. The user is in charge of interpolating such function for obtaining corrections relevant to its position. FKP can be performed through a 1-way broadcasting of corrections functions parameters to the user. The user has to be equipped with relevant processing capabilities (e.g. RTCM 2.3 message #59 or RTCM 3.0 corrections processing). A Cluster is usually composed at minimum by 5 Reference Stations.



4 Next Generation RTK: WARTK and WARTK-3

If a very accurate ionosphere errors estimation can be provided to the user, e.g. in the form of corrections grid, the distance separation among Reference Stations can be improved to hundreds of kilometres. Several algorithms have been studied during last years on this subject, with the involvement of ESA ([3]). They are referred as WARTK and concentrate their effort on the development of a real-time accurate ionospheric delays estimator through a Kalman Filter. The relevant extension to the future GNSS three frequencies, based on the application of TCAR ambiguity resolutions techniques, is named WARTK-3. TCAR techniques have been extensively studied by some years ([4]). They allow having a real instantaneous correct ambiguity fixing. The integration of WARTK with TCAR will allow reducing inherent limitations of TCAR (e.g. third step Ambiguity Resolution errors introduced by ionosphere biases and multipath errors) and providing a complete RTK European level service through a very low density network of Reference Stations. A high ambiguity fixing success rate has been obtained through simulations. Ionospheric corrections transmission latencies in the order of tenths of seconds and more are accepted.

EGNOS RIMSs, currently used for Wide Area code pseudorange augmentation, can be firstly used at this purpose and eventually densified with external Reference Stations (e.g. EUREF or IGS). Furthermore, EGNOS link (and SISNET) could be used for ionospheric corrections broadcasting to the user. Galileo Local Elements in the future, together with Commercial Services availability, will give the opportunity for Europe for having a first backbone of Reference Stations for the provision of a full coverage real-time European-wide high precision service.

Method	Advantages	Disadvantages
TCAR	Low computational load	Third step of ambiguity fixing limited by ionosperic error
WARTK	Accurate real-time ionospheric error modelling Precise navigation with Reference Stations separation of hundreds of Km	High convergence time
WARTK-3	Use of further widelaning possibilities and accurate ionospheric modelling Single-epoch precise navigation	

The development of accurate standards for WARTK corrections transmission to the user, as well as the integration of WARTK ionospheric corrections with rover generated ones is another step for WARTK solution.

5 The Reliability Problem

Another relevant problem currently slackening a full exploitation of High Precision applications is the evaluation of the RTK solution integrity at user level. Indeed, signal integrity is not sufficient for some applications.

This is particularly relevant for Safety of Life and Professional services. For the first class of applications, like port approach, inland waterways navigation, ADAS, etc., an integrity in the position domain for RTK should be provided. On the other hand, Professional applications (e.g. institutional cadastral surveying or high precision mapping), should guarantee surveying results. Here a wrong correct fix for a point implies repeating an entire survey, with relevant time and money waste. Integrity in the position domain for such applications can therefore improve GNSS High Precision market penetration in a relevant way. Future studies launched by ESA on WARTK will work on such issue.

6 High Precision Services, Networks and Mobile Communication Interoperability

High Precision Services infrastructures development is based on three main functional components:

- Control Centre, in charge of monitoring Reference Stations network status and of providing Real-Time Services or RINEX files to the user
- Communication Network between the Control Centre and Single Reference Stations
- Communication Network between Control Centre and rover

Concerning the Communication Network development between the Reference Station and the Control Centre, it is a critical component for Network-RTK technologies. In order to provide real-time corrections to the user, a continuous stream of raw data from each Reference Station has to be guaranteed. A reliable and high QoS communication network has to be implemented. Various experiences has been performed (e.g. using VPN or WAN/LAN) in many countries for the development of MRS/VRS networks. In any case the problem of the quality and relevant high costs for a reliable communication link is one of the major critical development factors that are slackening the development of such technology.

The solution is the reuse as much as possible of existing networks developed for Nation-wide organisations (e.g. institutional organisations), with favourable service contract with Communication Operators.

On the other hand, the Communication link between the Control Centre and the rover for getting a service is the other face of the same kind of bottleneck.

Starting from the oldest RTK solutions, where a set of modem was available for a GSM user dial-up and a Single Station (or the Control Centre acting as a router), current GPRS and future mobile communication systems (e.g. UMTS) are now offering TCP/IP connections. Major limitations of the GSM dial-up connection are GSM lack or low signal coverage (e.g. in rural or remote areas) and link robustness (every surveyor experienced the need for re-initialisations due to a link failure). Furthermore, GSM dial-up is quite expensive. In the case of 1Hz RTCM messages update, it could imply hundreds €/month for a surveyor daily work. Also in the case of flat RTK services price (as currently provided by some High Precision Service Providers, sometimes coincident with Mobile Operators), ranging in the order of 80–100 €/month, a relevant part of the price is due to connection cost.

GPRS, EDGE now or CDMA2000 and UMTS in the future are offering a relevant alternative from the point of view of Internet multicasting capabilities and the service price (based on packets based price figures), but similar problems in terms of link robustness and coverage are expected. A service price in the order of some hundreds of Euros is anyway a possible target without relevant service agreements with Mobile Operators. Other possible broadcasting systems are FM sub-carrier modulation using DARC (Data Radio Channel) or DAB (Digital Audio Broadcasting). WiFi and WIMAX are also emerging as broadcasting means.

Furthermore, other augmentation systems based on a fine real-time modelling of error sources and precise ephemeris are currently emerging, able to provide subdecimeter accuracies through satellite corrections broadcasting (e.g. Star-fire).

Needed bandwidth for RTCM 2.x messages transmission is in the order of 4.8kbps for 12 satellites for single-station RTK and in the order of 2kbps for RTCM 3.0 standards, while VRS corrections transmission bandwidth is in the same order of single-station RTK.

Within the framework of RTK corrections transmission standards, NTRIP (Network Transport of RTCM via Internet Protocol) is the latest development. It is a protocol based on HTTP/1.1 and is designed to broadcast GNSS corrections over the Internet and Mobile IP Networks. It is currently provided in version 1.0 by RTCM and used by EUREF and Network-RTK implementations in the world. Major Professional GNSS manufacturers are starting to integrate NTRIP processing within receivers and it is expected in a couple of years all the receivers will be equipped with such interface. Such protocol requires a few hundreds to few thousands bps. It has to be considered the preferred broadcasting protocol for Network-RTK.

Suitability of Control Centre to rover communication systems will also depend on the Network-RTK method to be developed. While VRS solutions occupation depends on the number of connected users (bi-directional link for each user), other network RTK solutions depend on the number of Reference Stations data to be transmitted.

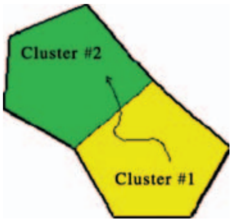
In any case, the number of data to be directly transmitted depends on the number of satellites. In the future over 12 GNSS satellites could be visible also in shadowed environments and in the order of 20 in Open Sky conditions.

The solution should be to start carrying out service agreements and systems integration between High Precision Service Providers and Mobile Communication

Operators in order to obtain more suitable service price for the user. Such integration should imply a guaranteed coverage and the improvement of the relevant QoS. Interoperability between Reference Stations and Mobile Communication systems can be performed through the architectural components foreseen for LBS services developments (GSM SMLC and UMTS SRNC).

Also in this case, National Institutional actors could drive such development for relevant professional activities (Port Operations, Land Surveying), leaving mass market to Mobile Operators.

Galileo, through the development of Local Elements, has the opportunity of implementing from scratch such kind of strategy.



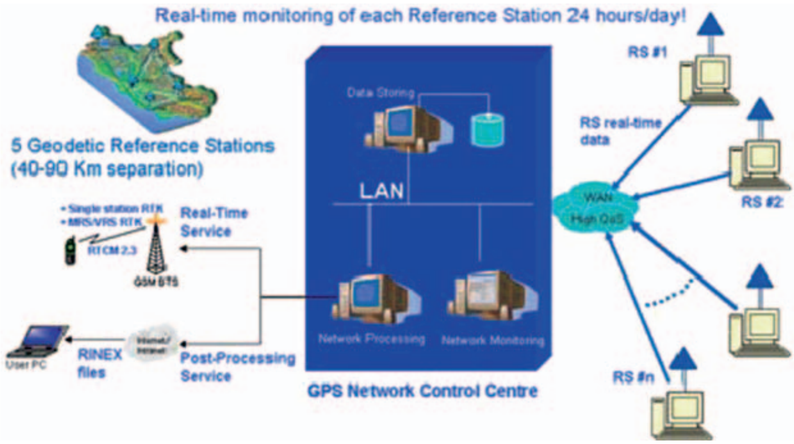
Handover is another relevant problem to be dealt with. Users moving from one Network-RTK Cluster to another should in fact coherently receive a new stream of corrections relevant for the belonging area. While in a VRS approach using bi-directional links, rover position can be updated and a new stream of VRS data transmitted after a Cluster change, a complete broadcast system, not aware of user position, cannot automatically perform such Cluster handover. Such limitation will become more important in the future, where mobile High Precision applications will grow. Such problem can be tackled in the future through WARTK very long-baseline Reference Stations architecture, allowing to provide ionospheric errors corrections for an entire Continental Area.

7 Networks Architectures and Developed Tests

Sogei, within its Institutional tasks, developed extensive R&D activities for maintaining technological leadership for the exploitation of its role of ICT technological partner of the Ministry of Economy and Finance Authorities (Revenues, Land, Customs and State Properties) of Italy.

Within the framework of Geomatics, Sogei participates to Galileo relevant EC Projects on high precision applications development (MARUSE and MONITOR) and it is member of the Consortium Galileo Services.

Concerning R&D activities on high precision surveying (of direct interest for Cadastre), a prototype MRS/VRS Network of five Reference Stations have been developed. The Network covers different environmental conditions (sea, lake, rivers and mountains). A state of the art VRS method based on a Differenced approach has been used for estimating network services performances in such worst case situation.

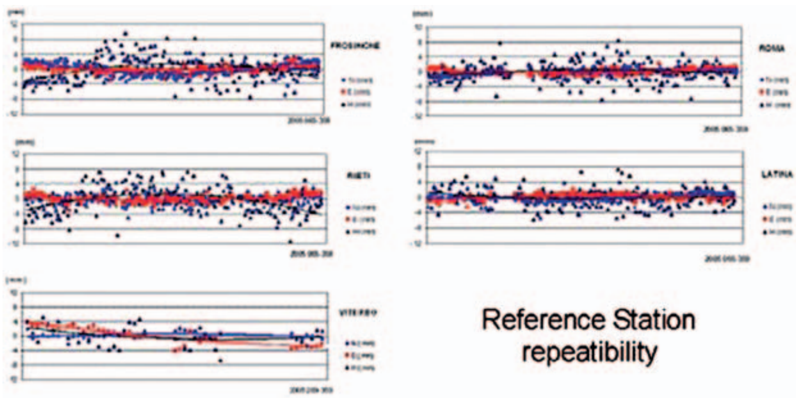


The main objective of such implementation has been to develop a prototype network infrastructure for evaluating Networks architectural constraints from an "Industrial" point of view for the development of a nation-wide MRS/VRS Network and relevant services. Indeed, more than a detailed test on Network performances in terms of accuracy and TTFA (for which an extensive literature exists), Sogei considers essential for a real and successful development of such services a full comprehension of implementation problems concerning Level of Services, Service Guarantee and Reliability. An analysis of constraints for the development of an infrastructure able to provide Professional and Institutional h24 services level has been developed at this purpose.

In the following, main results coming from such analysis developed for about one year of h24 Network monitoring are reported for an infrastructure potentially designed for providing such kind of services.

In order to evaluate interoperability and interfacing constraints, Reference Receivers and processing software from different manufacturers (scientific and commercial) have been integrated within the platform. An MRS/VRS Open software has been adopted for having the possibility of tuning relevant parameters and evaluating impacts on the Service Level. The communication link between the Reference Stations and the Control Centre has been developed using the high quality nationwide WAN network of the Italian Public Administration (RUPA), while GSM supported corrections transmission.

Extensive Post-Processing and VRS RTK tests have been developed within such network. Relevant results are coherent with the ones obtained in the world for similar systems (accuracy between 3 and 5 cm and TTFA in the range of 30s-3 min for most the cases, with millimetric RS repeatability). In order to evaluate land surveying and mapping performances, *Mixed* surveying (integrating traditional topographic and GNSS sensors) have been developed. Main considerations from the analysis are reported hereinafter in terms of requirements for developing such infrastructure:



Data Recording:

- About 2.8 GB/month per Reference Station (binary, RINEX files)
- Data recorded hourly at 1 s and daily at 30 s
- Daily automatic data conversion and Quality Check through teqc
- Automatic backup system and monthly storage on DAT
- Batch weekly Reference Stations Coordinates solutions (Bernese)

Communication links between Control Centre and Reference Stations

- High QoS (low latency, robust connection) Communication Networks between Reference Stations and Control Centre and Backup lines
- Real Open standards for raw data streaming from Reference Stations to the Control Centre (RTCM, BINEX, NMEA), with particular reference to ephemeris data
- Development of a distributed architecture, with completely automated Regional Clusters able to monitor and control a set of 5–8 Reference Stations and provide relevant post-processing and real-time services

Reference Stations installation

Availability of logistically equipped sites: power supply with UPS, Network connection all over a Nation (e.g. Public Administrations buildings).

Connection link between the Control Centre and the User

- Post-Processing: Web portal for RINEX data provisioning
- Real-Time: corrections multicasting through NTRIP protocol is the most suitable; it is anyway necessary to guarantee for 2–3 years the transition for users equipped with non-state-of-the-art receivers (e.g. RTCM 2.x interfaces only) through dial-up GSM services

Concerning logistics and engineering of the Control Centre for h24 services, the following critical operation should be performed:

- h24 operations of the Control Centre (provided with semi-automatic control chain at different service levels)
- Integration of different semaphore monitors controlling different architectural components (Communication Network, Reference Stations, Antennas integrity)
- Availability of Automatic Components Controllers (e.g. robots)
- Predictive algorithms for the communication network monitoring
- Customer Care and service assistance
- Availability of a local recovery operators for each Reference Station site and of a Maintenance teams for the whole Nation

Network Design Issues

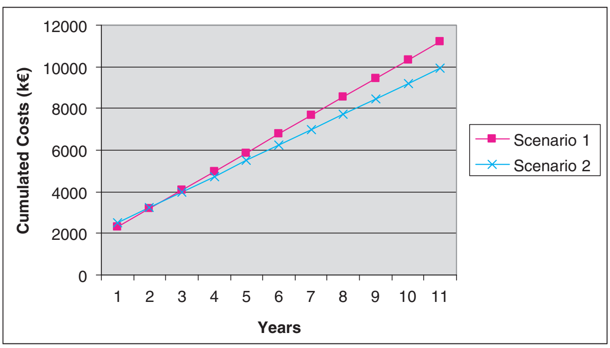
Concerning the Italian reality, some considerations can be carried out, valid for a general context:

- A National MRS/VRS Network design is necessary for guaranteeing uniform coverage and services: a backbone of Reference Stations distributed at national level and managed by an institution is necessary
- The adoption of a national Reference System based on such network, tied to IGb00, ITRF00 and ETRF
- Development of an *Open System* for the integration of best existing sub-networks able to integrate Reference Stations of different manufacturers and models

A comparative cost analysis for developing a Network-RTK in the Centre-Italy has been performed following two different approaches:

- Use of already existing network of Reference Stations and densification through new developed RS (Scenario 1)
- Development of a new backbone of Reference Stations (e.g. developed by a national institutional actor) and densification with existing networks (Scenario 2): use as much as possible of existing communication/logistic infrastructures owned by the National actors

The cost analysis, including Site monumentations, operations and communication networks costs, leaded to the following cost estimations. It can be seen how, after a few years, the development of RS Network by a unique National actor implies a

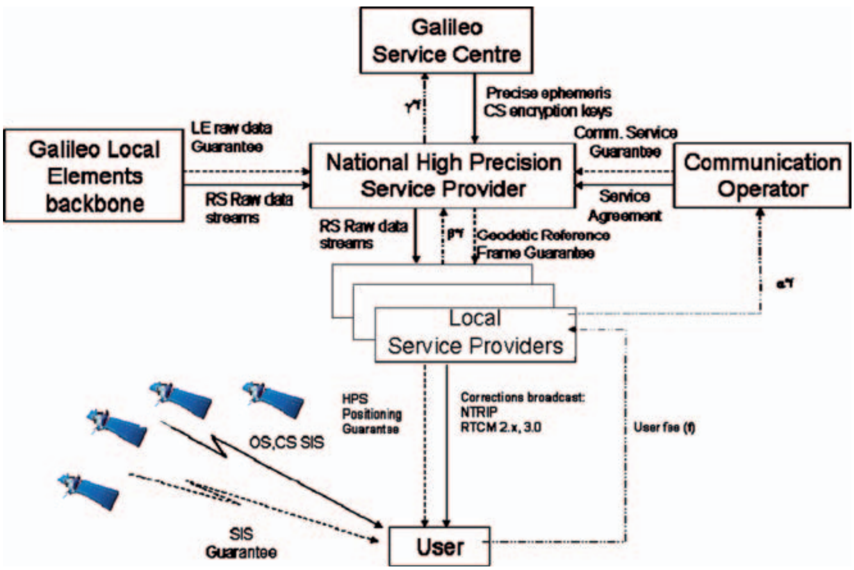


relevant cost saving with respect to a separate integration of existing sub-networks. This is in a great part due to the reduced communication network costs, thanks to previous Service Agreements with the Telecom Operator for a National Customer and reduced sites installation costs.

8 Galileo Local Elements and Business Models

Galileo Local Elements development will allow the definition of a Business Model for High Precision Services implementation at National and Regional Level. The Galileo Service Centre should be in charge of monitoring Commercial Services delivery, assigning Commercial Services encryption keys to National Service Providers and providing Standards for Galileo Local Elements Monumentation, Installations and Operations. National High Precision Services (a unique, possibly Institutional actor) should be responsible of developing at National level a backbone of LE for providing basic HPS. Such national backbone should be developed in MRS/VRS mode (or future WARTK-3). Local Service Providers within each nation can provide HPS and carry out a densification of the backbone. The National Service Provider has to provide a National Communication Network through relevant agreements with National Communication Operators in order to have high QoS at convenient rates.

A Liability Chain should be furthermore established. A *HPS Guarantee mask* of flags, one for each component involved into the chain (e.g. Communication link, Geodetic Frame, LE Raw data, Regulatory Bodies Certification, etc..), should be sent to the rover. A dedicated RTCM messages should be defined in the future for transmitting such Galileo Positioning Guarantee mask.



Concerning High Precision Service revenue stream, the National High Precision Service Provider can be the *Central collector of revenues*. Final User can pay Local Service Providers (or directly the National High Precision Service Provider). Part of such revenues should be passed to the Communication Operator and part forwarded to the GSC.

9 Conclusions

The future of High Precision Services is evolving due to Network-RTK and future WARTK technologies. The more HPS will be available, the more innovative applications will require such services (e.g. ADAS, Port approaches and Operations, High Precision mapping, etc.). The implementation of a High Precision Service at National levels implies the following:

- Definition of a National Service Provider (possibly Institutional), providing relevant logistics infrastructures and in charge of Reference Stations/LE developments
- Availability of a high QoS communication network (low latency, high robustness) through relevant agreements and links with GSM SMLC or UMTS SRNC and management of MRS/VRS Clusters handover
- Definition of h24 homogeneous HPS all over the territory through Predictive Systems for Communication performances monitoring
- Adoption of a national Reference System based on such network, tied to IGb00, ITRF00 and ETRF
- Development of real *Open System*, able to integrate best existing sub-networks (different models and manufacturers)
- Definition of Business Models: National Service Providers, to be the revenue stream collectors, and relevant relationships with Local Service Providers, Communication Operators, Institutions and GSC
- Definition of a HPS Service Guarantee mask of flags to be transmitted to the user through an RTCM message to be defined

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