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Agenda item [[2]](#footnote-2) 13

Technical Domain / Task Number 2 …………………………………

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Jorge Morán (ESSP), Juan Vázquez (ESSP)

Transmission of SBAS corrections over IALA beacons

# Summary

The present document provides a high level description of the potential solutions to broadcast DGNSS corrections generated from the EGNOS (SBAS) message (obtained from SIS and/or EDAS) over IALA beacons, including the definition of a high-level architecture, functional elements and interfaces.

The potential architectures and impact on reference solutions, based on the two general approaches (classic approach or network approach) defined in IALA Guidelines 1112 [1], are presented in the annex below.

## Purpose of the document

The purpose of the document is to provide this technical description for the Committee review in order to obtain comments and to be considered in the development of the associated IALA SBAS Guidelines.

# References

1. IALA Guideline No. 1112, Performance and Monitoring of DGNSS Services in the Frequency Band 283.5 – 325 kHz, Edition 1, May 2015
2. RTCM Standard 10401.2 for Differential Navstar GPS Reference Stations and Integrity Monitors (RSIM), December 18, 2006
3. RTCM 10402.3 Recommended Standards For Differential GNSS services, August 20, 2001
4. SISNeT User Interface Document, E-RD-SYS-E31-010, Issue 3, Rev. 1.
5. EDAS (EGNOS Data Access Service): Alternative Source of Differential GPS Corrections for Maritime Users, ION GNSS 2015.
6. EDAS Service Definition Document, Issue 2.1, December 19 2014 (<https://egnos-user-support.essp-sas.eu/new_egnos_ops/sites/default/files/library/official_docs/egnos_edas_sdd_v2_1.pdf>)

# Action requested of the Committee

The Committee is invited to consider the information provided in the Annex.

1. ANNEX 1: EGNOS based DGNSS service over IALA beacons

The present document provides a high level description of the solutions that could be implemented to generate DGNSS corrections from the EGNOS message (obtained from SIS and/or EDAS) and broadcast them over IALA beacons. This analysis includes the definition of a high-level architecture, functional elements and interfaces.

This information is structured as follows:

* Section 1: Overview of the DGNSS service over IALA beacons
* Section 2: High level architecture of the potential solutions for the implementation of an EGNOS based DGNSS service. The impact of setting-up an EGNOS based solution on the typical DGPS station architecture has been analysed in terms of:
  + Impact on each functional element of the DGPS station.
  + Changes required at the impacted functional element.
  + Impact on the interfaces and the way in which functional element of the DGPS station interacts with the other elements.
* Section 3: This section provides a comparison of the accuracy performances obtained with a traditional DGNSS solution with respect to an EGNOS Based VRS solution.

1. Overview of a DGNSS service over IALA beacons
   1. Introduction to IALA DGNSS

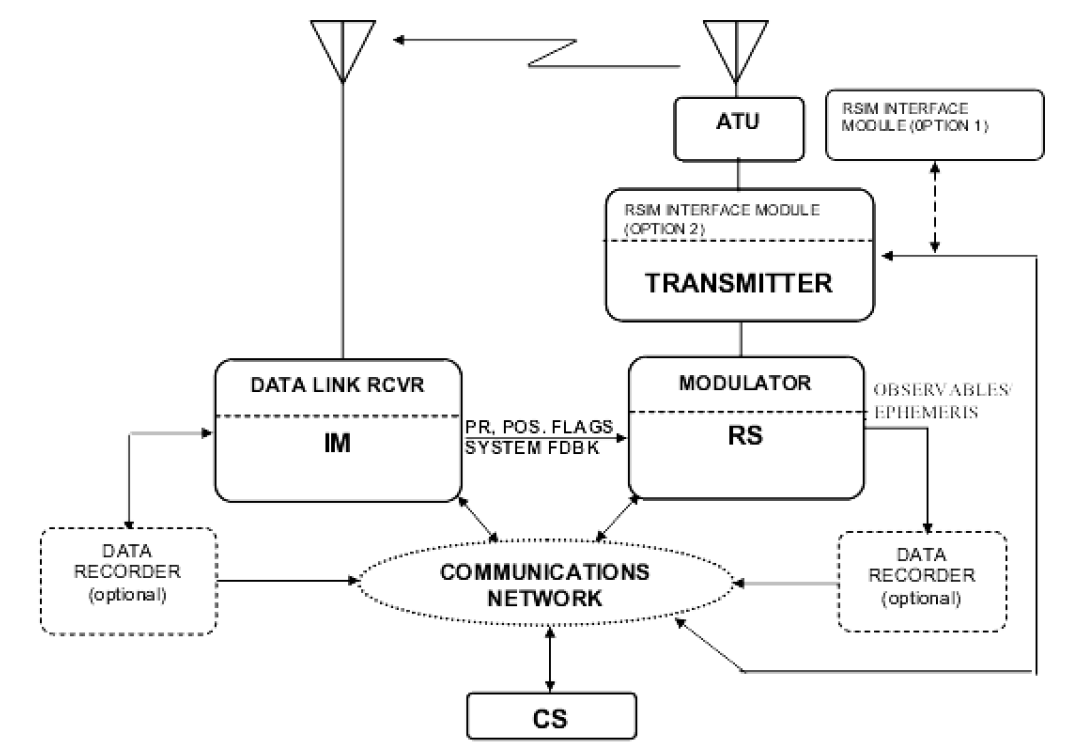
The internationally accepted method for providing GNSS augmentation in the maritime domain is the IALA DGNSS. IALA DGNSS provides corrections and integrity information to maritime users by means of local broadcast stations transmitting non-encrypted corrections on frequencies within the MF maritime radio navigation band (283.5 to 325 kHz).

The IALA DGNSS employs the principle that the main sources of error in satellite navigation (i.e. satellite clocks errors, satellite ephemeris errors, tropospheric and ionospheric delay estimations errors) are highly correlated for two users located relatively closed to each other. Differential GNSS corrections are computed by placing a reference station with a GNSS receiver at a known location, determining corrections to the satellite ranging signals, and broadcasting these corrections to users. This removes the bias errors common to the reference station and user receivers, and improves the positional accuracy. The accuracy is then limited by user receiver noise, inter-channel biases, user local effects and differential station location uncertainty.

On the other hand, the IALA DGNSS Integrity concept is based on an Integrity Monitoring (IM) station that retrieves the corrections broadcast (or to be broadcast) by the Reference Station (RS) and verifies that the information is within tolerance (both at pseudorange and position domain levels) based on the fact that the position of the IM is known. Two different integrity approaches are possible, depending on whether the integrity check is done before or after broadcasting the corrections to the users: Pre-Broadcast Integrity or Post-Broadcast Integrity [2].

* 1. IALA DGNSS System architecture

The following figure shows the architecture of a traditional DGNSS system station:



1. DGNSS System architecture [2]

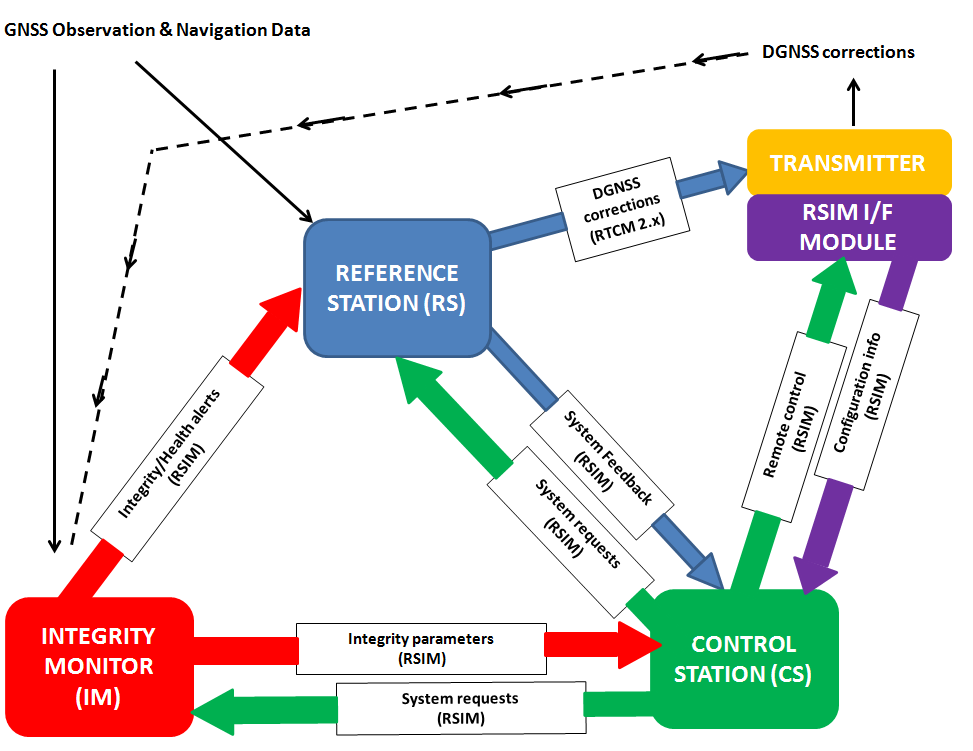
The main elements providing the key functionalities are described in more detail below:

* **Reference station (RS)**: it computes the Pseudorange Corrections for satellites above the elevation mask. PRCs and ancillary information (e.g. antenna location) are formatted per RTCM 10402.3, modulated within the RS and output to the transmitter.
* **Integrity Monitor (IM)**: it checks the integrity of the DGNSS corrections generated by the RS, both at pseudorange and position domain levels. An integrity monitor may generate alarms for a particular reference station or report alarms for whatever broadcast is received.
* **Transmitter**: it broadcasts the messages provided by the Reference Stations.

Other components of a DGNSS system are:

* **Control station (CS)**: it provides real-time system monitoring and control of the functional and performance status of remote DGNSS broadcast sites, supplies network status information to the broadcast site and collects and manages performance data from the broadcast sites.
* **Communications**: Many types of communications links could be used to connect the RS, IM, CS and other components. For example, a specific implementation could co-locate the RS and the IM at the transmit site, and provide wide area communications with the CS.
  1. Functions and interfaces

The following diagram provides a high level view of the main data flows between the IALA DGNSS stations components together with an indication of the type of data that is exchanged. The figure is based on the post-broadcast integrity monitoring concept, where the IM is getting the corrections broadcast by the Transmitter (computed by the RS) just like any actual user would do.



1. IALA DGNSS station interfaces (Post-Broadcast Integrity) [2]

In the case of the pre-broadcast integrity monitoring concept, the only difference with respect to the diagram depicted above, is that the RS station sends the computed corrections to the IM before broadcasting them.

1. EGNOS Based DGNSS Service
   1. Introduction

This section provides a description of the changes (with respect to the baseline architecture above) that would be required to set-up an “IALA DGNSS service” using EGNOS messages as input to compute the differential GPS corrections.

As described in the IALA Guideline 1112 [1], marine beacon infrastructure can be considered to fall into these two different architectures, with either equipment all sited at the broadcast locations (**classic approach**), or some of the infrastructure is centralized with only the transmitting equipment at the broadcast site (**network approach**).

Taking into account these two general architectures, two different solutions for the provision of EGNOS based DGNSS corrections are described in the following sections: Decentralised (classic approach) and centralised (network approach).



1. DGNSS Service Architecture: Classic and Network Approach [1]

For this analysis, the following principles are considered:

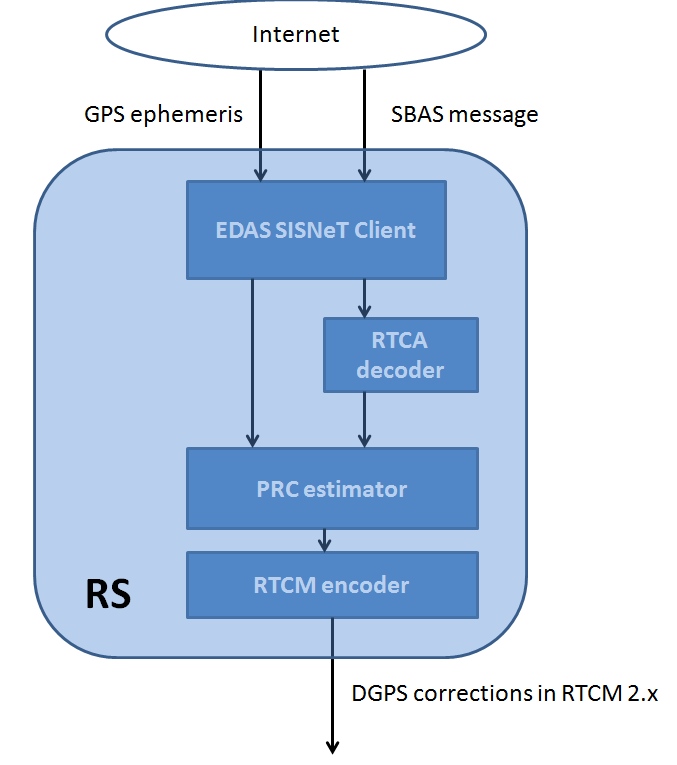
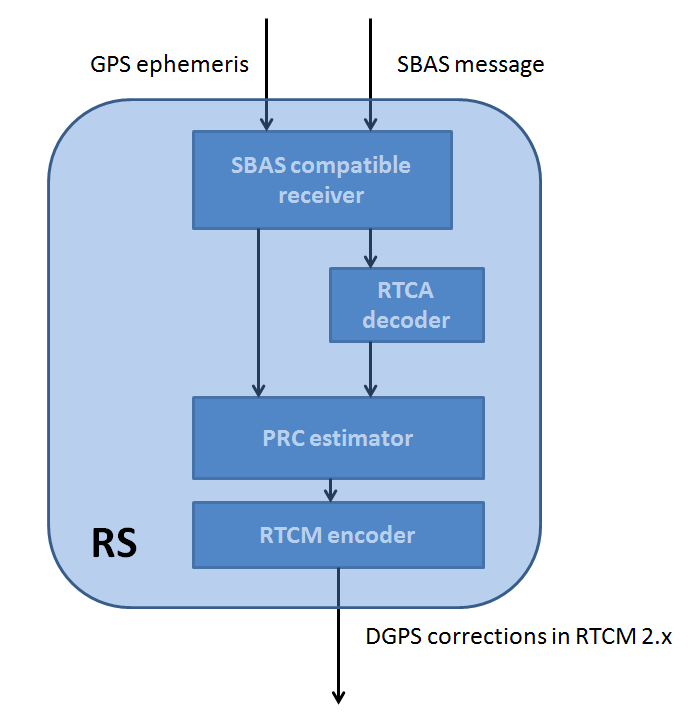
* Independent integrity monitoring function needed, being performed locally at/close to the RS. Both pre and post broadcast integrity monitoring concepts are considered.
* Redundancy is not a requirement, but something up to the DGPS service provider to define, depending on the application requirements and network topology. However, it is noted that in order to meet the availability requirements [1], redundant solutions together with overlapping coverage areas are typically implemented. For instance, in order to mitigate the potential risk of communication failure in a centralized solution, one option is to duplicate the communication lines, but other option is to combine the generation of EGNOS Based Virtual Reference Stations in a central facility with the computation of DGNSS corrections (either based on EGNOS or using a traditional DGNS station) locally at each broadcast site.
  1. General Architecture of a Decentralised EGNOS based DGNSS service over IALA beacons

This section describes the components of a traditional DGNSS station (see section 1.2) that shall be modified or replaced for the provision of EGNOS based DGNSS corrections in a decentralised architecture.

As detailed hereafter, the only module that needs to be modified with respect to the traditional DGNSS architecture is the Reference Station (including also the GNSS Receiver).

Regarding the GNSS receiver, two options are considered for the access to the EGNOS data: SIS and EDAS [6].

1. SiS: the source for the generation of the DGPS corrections (RTCM 2.x) to be broadcast by the transmitter is the EGNOS Signal in Space. The required changes at the RS are the following ones:
   * The receiver can no longer be a GPS only receiver, it has to be SBAS compatible and able to provide as an output the SBAS messages transmitted by the EGNOS GEO satellites.
   * The RS software shall be modified to produce the differential GPS correction taking the SBAS messages as input. It would basically consist of an RTCA to RTCM converter.
2. EDAS: the source for the generation of the DGPS corrections (RTCM 2.x) to be broadcast by the transmitter is the EGNOS message received from EDAS. The required changes at the DGPS stations are the following ones:
   * A GPS/EGNOS receiver is no longer needed at the RS, since access to the EGNOS message and also to the GPS ephemeris is now done through the internet. Hence, instead of a receiver, the RS would need to have an internet connection. It should be noted that depending on the architecture of the existing DGPS service the need for an internet connection may not be a new communication interface. One CS could serve multiple DGPS stations and hence, an internet connection would already be available at the RS.
   * The RS software shall be modified to produce the differential GPS corrections taking the SBAS messages and the GPS ephemeris as input from EDAS. It would basically consist of a SISNeT client and a RTCA to RTCM converter.



1. EGNOS based DGNSS station: RS block diagram

It should be noted that, when connecting to EDAS SISNeT service, one has to choose between the two operational EGNOS GEO satellites. Hence, in order not to penalize the availability of the GPS corrections with respect to the option based on the access to the EGNOS messages through the SIS (SBAS compatible receiver is capable of tracking multiple GEOs), two SISNeT clients shall be used, each of them connected continuously to one EGNOS GEO satellite. Then, the SW to convert from RTCA to RTCM should include a GEO switch function.

The remaining elements in the baseline architecture do not need to be modified for the following reasons:

* IM: all inputs/outputs are the same and hence the same architecture/elements are required:
  + Corrections will be in RTCM format in any case, accessed after broadcast by the transmitter (post-broadcast integrity monitoring) or from the corresponding RSIM message delivered by the RS (pre-broadcast).
  + The feedback to be sent to the RS is not modified.

If the post-broadcast integrity monitoring concept is used, the IM will need to have a DGPS receiver to access the GPS measurements from the satellites.

* CS, transmitter: their functions are not depending on the algorithm and/or inputs for the corrections computation/generation.
  1. General Architecture of a Centralised EGNOS based DGNSS service

This section provides a description of the changes (with respect to the baseline architecture) that would be required to set-up a “Centralized EGNOS Based DGNSS” service.

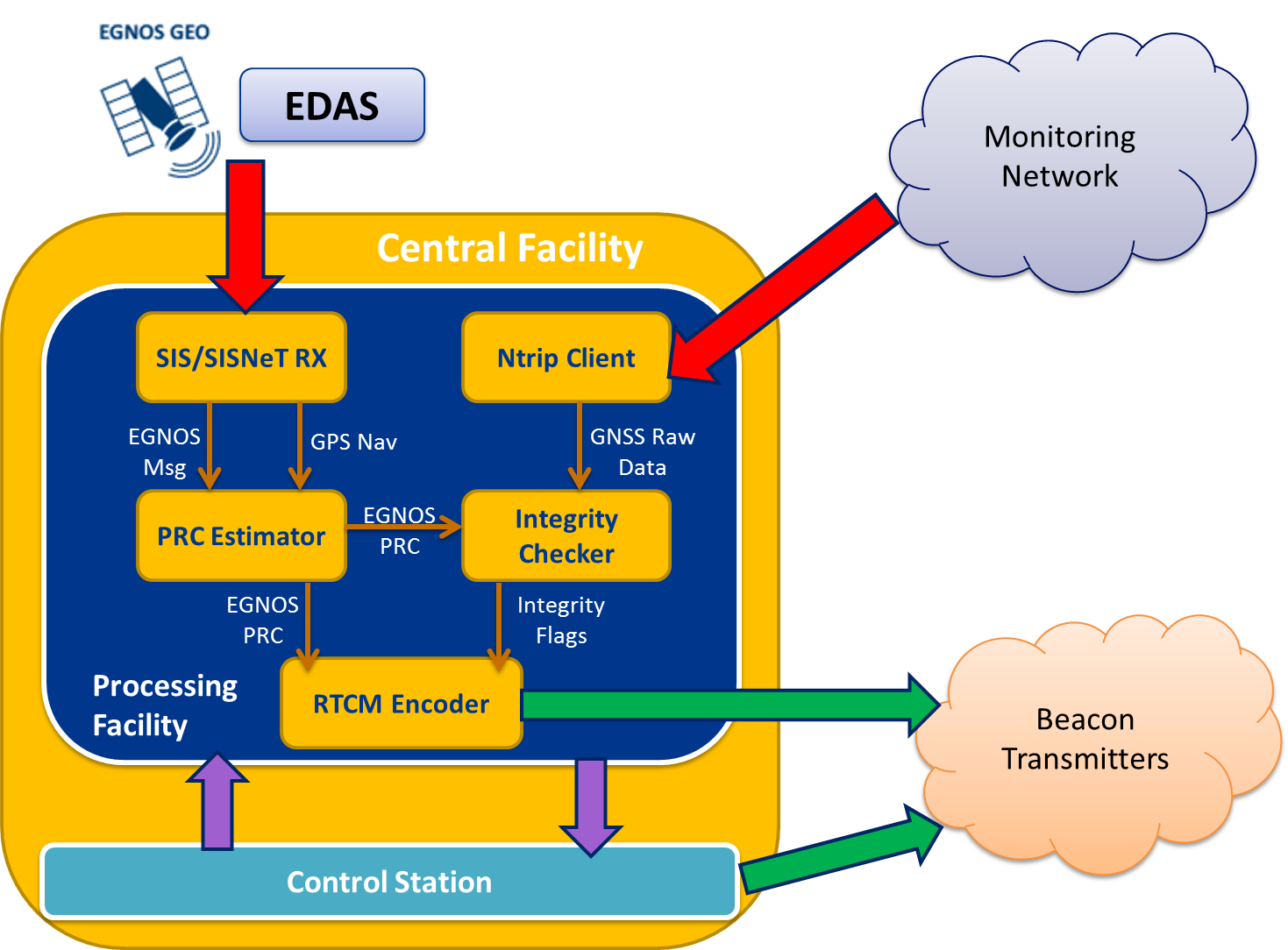
It is noted that this solution corresponds to the network approach described in the IALA Recommendation 1112 [1]. In line with this recommendation, the Pre-broadcast integrity monitoring concept is considered for this analysis (page 21 in [1] reads “*for the network approach, the integrity monitoring is based on the Pre-Broadcast Monitoring (PBM) algorithm*”).

At high level, the architecture of a centralised EGNOS based DGNSS service comprises the following elements:

* **Central Facility (CF)**, responsible for the generation and integrity monitoring of the PRC corrections.
* **Monitoring Network**, providing GNSS raw data to monitor the integrity of the EGNOS based PRC corrections.

It is noted that the service provider is also recommended to have a network of MF receivers distributed throughout the service area in order to monitor the service availability: “*The service provider should take the degree of coverage from multiple beacons into account when validating the service availability*” (see [1], page 23).

* **Beacon Transmitters Network**, responsible for the transmission of the corrections computed by the CF to the final users.



1. High level Architecture – EGNOS
   * 1. Central Facility

The Central Facility is the main component of a centralised EGNOS based DGNSS service. The primary function of the Central Facility is to compute the Pseudorange Corrections for all the satellites above the elevation mask. PRCs and ancillary information (e.g. antenna location) are encoded into RTCM 10402.3 and transmitted to each beacon transmitter site.

Also, the Central Facility may include as well the Control Station, whose role is to provide real-time system monitoring and control of the functional and performance status of remote DGPS broadcast sites, supply network status information to the broadcast site and to collect and manage performance data from the network of broadcast sites.

Therefore, the main two elements of the Central Facility are the **Processing Facility**, responsible for the generation of the DGNSS corrections in RTCM 10402.3 format [3] and the **Control Station**, providing capabilities for real time system status monitoring and control of the functional and performance parameters of remote DGPS broadcast sites.

* + - 1. Processing Facility

As detailed in Figure 5, the Processing Facility is responsible for the computation of the DGNSS corrections in RTCM 10402.3 format [3]. The source for the generation of the DGPS corrections to be broadcast by the transmitter could be the EGNOS Signal in Space or the EGNOS messages received from EDAS.

Also, in order to check the integrity of the corrections computed based on EGNOS, the Central Facility processes the GPS raw data received from a network of GNSS receivers. This network could be a dedicated/proprietary one (set of receivers specifically deployed within the coverage area) or a GNSS networks provided by an external entity (public or private).

A detailed description of the elements comprising the Processing Facility is provided below:

**EGNOS SIS or SISNeT Receiver**

The source for the generation of the DGPS corrections to be broadcast by the transmitter could be the EGNOS Signal in Space or the EGNOS messages received from EDAS.

1. SiS: In case the EGNOS messages are obtained from the EGNOS SIS, an SBAS compatible receiver is needed. It should be noted that the receiver should be able to provide as output the raw data, mainly the GPS navigation message and the EGNOS corrections.
2. EDAS: The other option is to obtain this information from the EDAS SISNeT Service, providing access to the EGNOS GEO satellites messages transmitted through internet using the SISNeT protocol [4]. This protocol, not only allows the users to receive on real-time the EGNOS message through internet but also the GPS navigation data, required for the RTCA to RTCM conversion. As detailed in [4], ephemeris information for a given GPS satellite can be obtained upon request by the user. The ephemeris information is expressed in a RINEX-like format. As commented before, two SISNeT clients shall be used, each of them connected continuously to one EGNOS GEO satellite. Then, the SW to convert from RTCA to RTCM should include a GEO switch function.

In order to duplicate the data acquisition, it is also possible to deploy both solutions: SBAS enabled receiver and EDAS SISNeT Client. Thus, in case of failure in any of these components, the service is not affected.

Independently on whether the EGNOS message and GPS navigation data is obtained from an EGNOS compatible receiver or from the EDAS SISNeT service, the main functionality of this module is to implement a real-time interface for the reception of this data on a second by second basis, and to provide the EGNOS message in RTCA format and the ephemeris to be injected to the PRC estimator module.

**PRC Estimator**

The primary function of the PRC estimator is to compute the Pseudorange Corrections for satellites above the elevation mask angle for each Virtual Reference Station (VRS). In order to compute these corrections, the PRC Estimator uses as input the following information:

* Beacons location: This could be obtained from a configuration file, containing the antenna position (WGS-84 datum) for each VRS location.
* GPS Navigation message: GPS ephemeris are provided by the “EGNOS SIS or SISNeT receiver” and are used to perform the RTCA to RTCM conversion.
* EGNOS corrections in RTCA format.

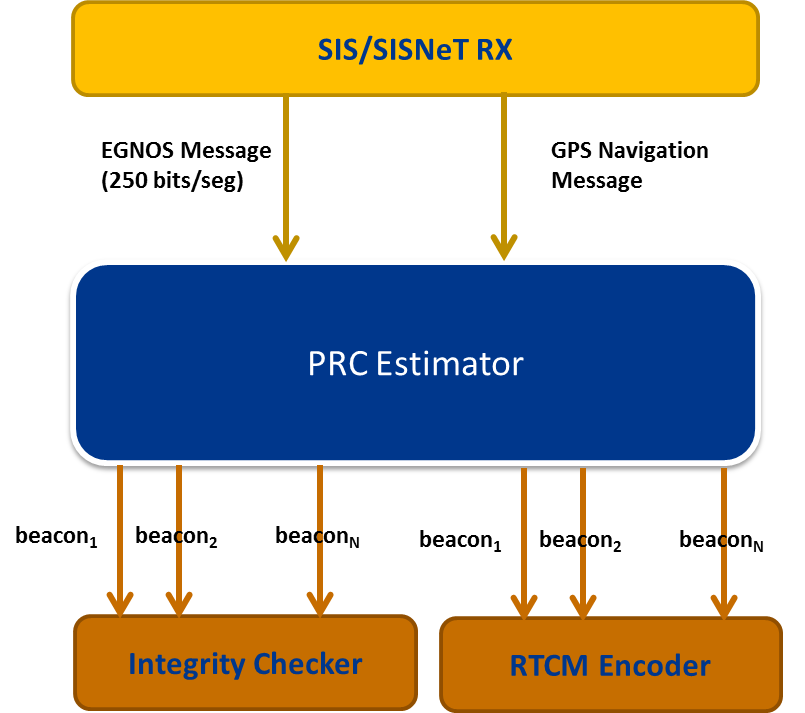
Therefore, for each VRS, the PRC estimator needs to compute the number of GPS satellites in view (based on the navigation message) and for each LoS estimate the pseudorange correction based on the orbit, clock and ionospheric corrections provided in the EGNOS message and other static information (tropospheric models). For the sake of clarity, the Pseudorange corrections calculated mapping EGNOS differential corrections into RTCM format will be called E-DGNSS PRC.

Focusing on the provision of **integrity information**, a double layer scheme could be used:

* **First level**: EGNOS integrity alerts mapped into RTCM 10402.3 format [3].
* **Second Level**: Position and pseudorange integrity checks done using the E-DGNSS corrections and the GPS measurements collected by a GNSS receiver within the coverage area (function performed by the IM in the typical IALA DGNSS station).

The “PRC Estimator” module will implement the so called first integrity level. EGNOS integrity alerts are mapped into RTCM 10402.3 [3] by setting the DGNSS MT1/9 PRC field to binary 1000 0000 0000 0000 for all the satellites flagged as “Don’t Use” or “Not Monitored” by EGNOS.

In terms of interfaces, the following diagram depicts the “PRC Estimator” component data flows.



1. PRC Estimator data flows

As shown above, the E-DGNSS corrections (including EGNOS integrity alerts) computed by the PRC estimator are transmitted to the Integrity Checker module. The Integrity Checker implements the classical pre-broadcast integrity concept by applying the E-DGNSS corrections to the GPS raw data collected by the Integrity Monitoring network.

**Ntrip**[[3]](#footnote-3) **Client**

In order to check the integrity of the E-DGNSS corrections, it is necessary to have access to GPS measurements collected from a receiver located within the coverage range of each beacon transmitter site.

One option is to have a dedicated GNSS receiver within the coverage range of each beacon transmitter. These receivers shall be capable of transmitting (via a suitable communication link) the GNSS raw data collected to the Central Facility. Another option could consist on obtaining this information from one of the several networks of receivers providing their GNSS measurements through internet via Ntrip (e.g. EDAS).

In any case, the raw data collected by the GNSS receivers would be transmitted to the Central Facility via internet using the Ntrip protocol.

Therefore, the Central Facility shall implement a module responsible for retrieving the GNSS data from the network of receivers located along the area of service. The main tasks of this module are:

* To manage the Ntrip communication with the different receivers.
* To select an available GNSS receiver within the coverage range of each beacon transmitter. In case of failure of one of these receivers, this module shall be able to switch to another receiver within the coverage range.
* To process the information collected (GPS measurements) from the receivers and distribute this data to the Integrity Checker module.

**Integrity Checker**

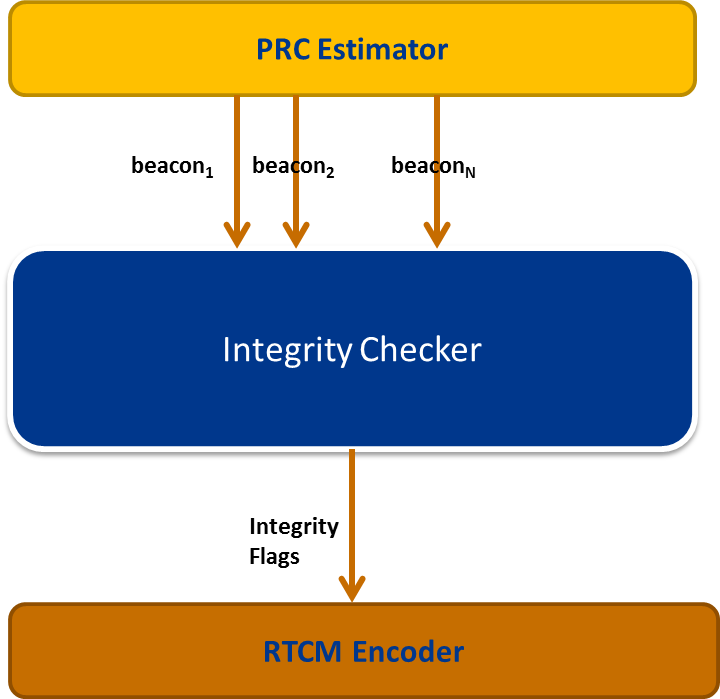
The pseudorange corrections computed by the “PRC Estimator” are processed by the Integrity Checker. This module, using as input the E-DGNSS corrections previously generated, the raw data collected by the Monitoring Network and known information (Receiver position, maximum acceptable error per line of sight after applying corrections –UDRE-), checks the integrity of the corrections both at the Position and the Pseudorange domains.

Finally, the E-DGNSS corrections computed by the PRC estimator along with the integrity flags set by the Integrity Checker are provided to the “RTCM encoder” module, responsible for encoding all this information in RTCM 10402.3 format. The above integrity function is equivalent to the one currently applied in IALA DGPS stations for the pre-broadcast integrity monitoring concept [2], since the same checks (no more no less) are performed.

It is important to remark that the **pre-broadcast integrity concept** is in line with the RSIM Standard [2] and the IALA Recommendation 1112 [1], where it is stated that “*For the network approach, the integrity monitoring is based on the Pre-Broadcast Monitoring (PBM) algorithm, which ensures that all relevant checks have been performed before DGNSS data are transmitted.”.*

It is also noted that in the classic concept shown in Figure 3, the approach followed by most of the Aton providers is the Post-Broadcast Monitoring concept. This monitoring concept, not only monitors the integrity of the data but also the availability of the radio link and the quality of the signal transmitted. This is one of the major differences with respect to the Pre-Broadcast concept (for the network approach) which only includes the integrity monitoring functionality, but does not check the availability of the MF radio link.

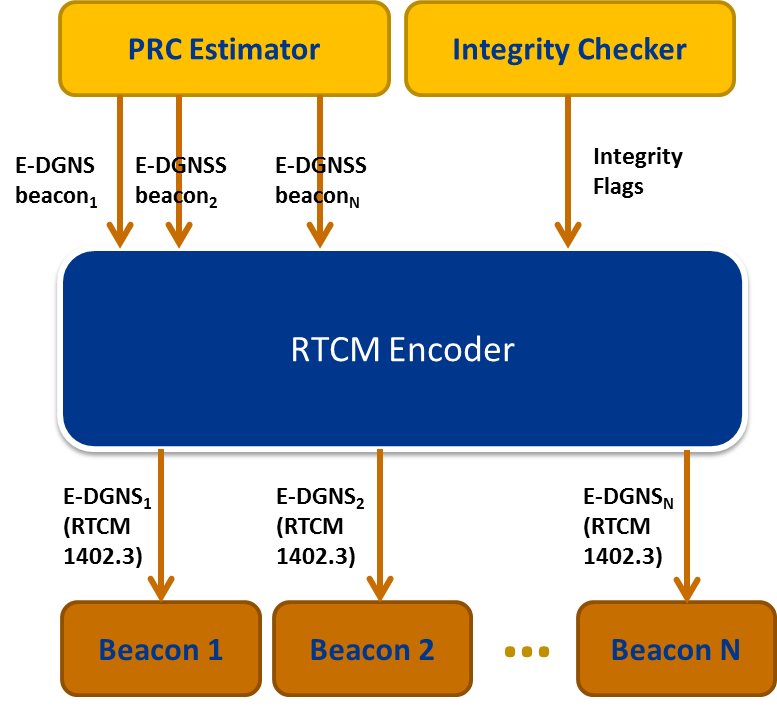
Taking into account that service provider shall ensure and monitor the service availability within the service area, IALA recommends [1] to implement signal far field monitors in order to monitor the signal strength of the MF radio link. Therefore, apart from the GNSS sensors needed to monitor the integrity of the data transmitted (based on the Pre-Broadcast concept), it is recommended to have a network of MF receivers to monitor the service availability and the quality of the signal transmitted.



1. Integrity checker data flows

**RTCM Encoder**

This module generates the RTCM 10402.3 data streams for each VRS using the pseudorange corrections computed by the “PRC Estimator” and the integrity flags provided by the “Integrity Checker”.



1. RTCM encoder data flows
   * + 1. Control Station

The Control Station (CS) provides capabilities for real time system status monitoring and control of the functional and performance parameters of remote DGPS broadcast sites. More specifically, the role of the control station is to ascertain the functional status of the broadcast sites which are assigned to it in a network, set the broadcast site parameters, control the broadcast site functions, supply network status information to the broadcast sites for dissemination, and to collect and manage various types of performance data from the network of broadcast sites [2].

* + 1. Monitoring Network

As detailed before, the Central Facility needs to have access to GPS measurements collected from a receiver located within the coverage range of beacon transmitter.

One option is to have a dedicated GNSS receiver located within the coverage range of each beacon transmitter. These receivers shall be capable of transmitting (via a suitable communication link) the GNSS raw data collected to the Central Facility.

Another option could consist on obtaining the GNSS raw data (needed for the integrity monitoring) from one of the several networks of receivers providing their GNSS measurements through internet via Ntrip. For instance, GPS and GLONASS raw measurements (via Ntrip protocol) may be obtained free of charge from EDAS (see Figure 9 for distribution of EGNOS RIMS in Europe).



1. EGNOS RIMS Stations RTCM encoder data flows

As mentioned before, the integrity monitoring approach presented in this document is based on the Pre-Broadcast integrity concept, using a network of GNSS sensors in order to monitor the integrity of the data transmitted. However, the service provider shall also ensure and monitor the service availability within the service area. Therefore, apart from the GNSS sensors used to implement the Pre-Broadcast Integrity monitoring, the service provider is recommended to have a network of DGNSS receivers to monitor the service availability and the quality of the signal transmitted [1].

* + 1. Beacon Transmitters Network

The last component of a Centralised EGNOS based DGNSS service are the beacon transmitters, responsible for the transmission of the corrections to the final users in the band between 285 and 325 kHz. This component remains unchanged.

In general terms, the E-DGNSS corrections transmitted by the Central Facility and modulated using the MSK (Minimum Shift Keying) modulation technique. The transmitter receives the MSK modulated signal, amplifies and sends it to the antenna, through tuning unit (ATU).

1. Expected performance level of an EGNOS based DGNSS service

This section presents a comparison of the performances obtained with a traditional DGNSS solution (for medium and large baseline lengths) with respect to the accuracy results provided by an EGNOS based DGNSS solution (named VRS in the article), which was presented in the ION GNSS 2015 paper “EDAS (EGNOS Data Access Service): Alternative Source of Differential GPS Corrections for Maritime Users” [5].

The results provided in this article, demonstrates that the performance obtained with the EGNOS Based DGNSS corrections (yellow line) are comparable with the results obtained with a traditional DGNSS solution (red line).

The following figure depicts the degradation of the DGNSS performances over different baseline lengths: short (<50km), medium (200-350km), large (350-500km).

|  |
| --- |
| Short Baseline (<50 km) |
|  |
| Medium Baseline (200-350 km) |
|  |
| Large Baseline (350 – 500 km) |
|  |

1. Probability density functions of horizontal error [5]

As mentioned before, DGPS is based on the fact that satellite and signal propagation errors for two users located relatively closed to each other are highly correlated and hence can be cancelled out when using the error information from a reference station (calibrated position). EGNOS, as any SBAS system, is also providing corrections to the same errors, with one exception: the troposphere. For this error source, SBAS systems do not provide corrections; users are expected to apply a model to reduce the error in the position due to this effect.

Hence, EGNOS based DGPS corrections are expected to be slightly worse than pure DGPS ones (actual measurements provide more accurate information on the troposphere error than a static model), especially for short baselines. This can be observed in the previous figures, where the pure DGPS solution is more accurate for short baselines (<50 km) but for medium and large baselines, the EGNOS based corrections provide the similar accuracy performance or even better (note that page 7 in [1] reads “*Typically, DGNSS services achieve an accuracy in the order of <5m (95%)*”).

1. Conclusion

The present document includes a detailed analysis of the architecture, functional elements, interfaces and responsibilities of each of them within an EGNOS DGNSS (decentralized and centralized solution) to be used for maritime navigation based on [1] and [2]. After the above analysis, the following main conclusions can be obtained:

* For the decentralised solution (classic approach), the integration of EGNOS in the baseline DGPS station architecture as source for the computation of the DGPS corrections is possible with changes impacting only the RS (Reference Station). The remaining functional elements would not be affected and the internal interfaces would be kept.
* Infrastructure reduction could be achieved with an EGNOS based centralized solution, thanks to the HW infrastructure reduction in the broadcast (remote) sites. The Reference Station, Control Station, Integrity Monitor and Transmitter elements present on each broadcast site on a traditional DGNSS architecture could be replaced by a Transmitter module.
* For the centralised approach (network-based approach), the availability of a communication infrastructure connecting the Central Facility with the Beacon Transmitters and the Monitoring network is essential. Therefore, the savings of the EGNOS centralised solution may depend on the communication infrastructure available and also on the level of redundancy required for the communication lines.
* Other important factor to be considered for the centralised solution is the data source for the integrity monitoring. Two options have been presented in this document: to have dedicated GNSS sensors within the coverage range of each beacon transmitter site or to rely on public/private GNSS networks to obtain the GPS raw data needed to perform the integrity monitoring checks (with the associated reduction of costs, in terms of deploying the GNSS receivers and also in terms of maintenance and operation costs).
* Finally, an indication of the achievable accuracies with a standard DGPS and an EGNOS based one has been provided. The information that has been presented indicates that, even if some degradation could be expected when basing the DGPS corrections on the EGNOS messages, the achievable performance is comparable (i.e. absolute horizontal accuracy <5m 95% [1]) and could be considered as sufficient (for most applications).

1. Input document number, to be assigned by the Committee Secretary [↑](#footnote-ref-1)
2. Leave open if uncertain [↑](#footnote-ref-2)
3. Networked Transport of RTCM via Internet Protocol (Ntrip) is a protocol for streaming differential GPS data (and GNSS data in general) over the Internet in accordance with specification published by RTCM. [↑](#footnote-ref-3)