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Transmission of SBAS corrections over AIS

# Summary

The present document provides a high level description of the architectures that could be used to generate DGNSS corrections from the EGNOS message (obtained from SIS and/or EDAS) and broadcast them over AIS base stations, including the definition of a high-level architecture, functional elements and interfaces. The architectures presented in this paper have been defined avoiding any impact on the internal components/elements of the AIS service.

In order to consider different AIS services topologies, two alternatives for the provision of EGNOS corrections via AIS have been analysed:

* EGNOS based DGNSS solution over decentralised AIS service
* EGNOS based DGNSS solution over centralised AIS service

## Purpose of the document

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

# References

1. IALA Guideline No. 1029 On Ship-Borne Automatic Identification System (AIS) Volume I Part II: Technical Aspects Of AIS, Edition 1.1, December 2002
2. IALA Recommendation A-124 Appendix 16 – DGNSS Broadcasts from an AIS Service
3. IALA Recommendation A-124 Appendix 4 –Interaction and Data Flow Model December 2011
4. EDAS (EGNOS Data Access Service): Alternative Source of Differential GPS Corrections for Maritime Users, ION GNSS 2015.

# Action requested of the Committee

The Committee is invited to consider the information provided in the Annex and provide feedback and comments.

1. ANNEX 1: EGNOS based DGNSS service over AIS

Two different solutions are analysed in this document for the generation of differential GNSS corrections to be transmitted by AIS base stations, depending on the existing AIS service architecture:

* EGNOS based DGNSS solution over decentralised AIS service (based on the use, locally at the AIS station of the EGNOS corrections accessed through the SIS or EDAS)
* EGNOS based DGNSS solution over centralised AIS service (for the generation of virtual corrections for each AIS base station in a central facility).

The sections below include an analysis of the AIS Service Architecture, based on the IALA documentation. Then the potential high level architectures for the transmission of the EGNOS corrections are presented, defined to avoid any impact on the internal components/elements of the AIS service.

This information is structured as follows:

* Section 1: overview of the AIS Service Architecture
* Section 2: overview of the transmission of DGNSS corrections via AIS
* Section 3: High level architectures of a EGNOS based DGNSS service over AIS

1. AIS Service Architecture Overview

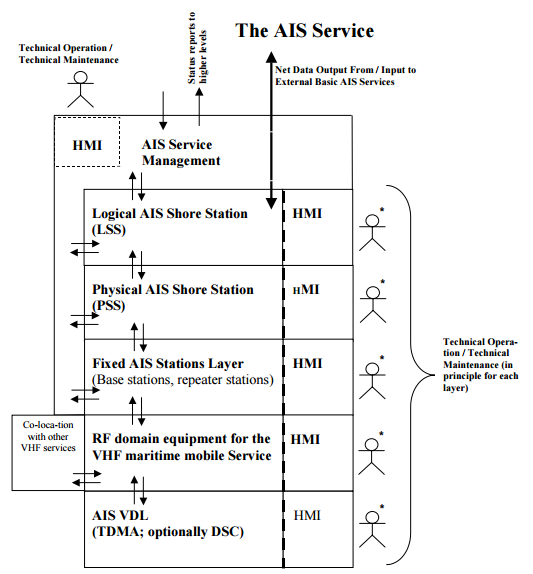
This section presents an analysis of the current architecture of the AIS service, so as to assess the impact (if any) of providing EGNOS based DGNSS corrections.

As described in the IALA Guidelines on the Universal Automatic Identification System (AIS) [1], the three main functional layers of an AIS service are:

* The **AIS-Service Manager (ASM)** provides for the management of the entire AIS service. This includes configuration and monitoring of all components and an HMI for technical personnel to do the configuration and monitoring.
* The **AIS-Logical Shore Station (LSS)** acts as a software router for AIS data going to and from the clients and the AIS PSS Controlling Units (AIS-PCU). It is responsible for the management of client and AIS-PSS connections, filtering of data on either or both connections, and data logging.
* The **AIS-Physical Shore Station (PSS)** is the site where the AIS data transmitted from ships is received.” The major components of an AIS-PSS are:
  + an AIS-PCU that is in charge of controlling one or more AIS fixed stations;
  + at least one AIS fixed station (AIS base station, AIS simple repeater or AIS duplex repeater) that provides the interface to the VDL (VHF Data Link). The AIS base station is the most fundamental building block of the Fixed AIS Stations Layer of the AIS service.

The present analysis will be focused on the AIS base station which is the component responsible for retrieving the DGNSS corrections (via a dedicated port), generate the MT17 and transmit it through the VDL channel.

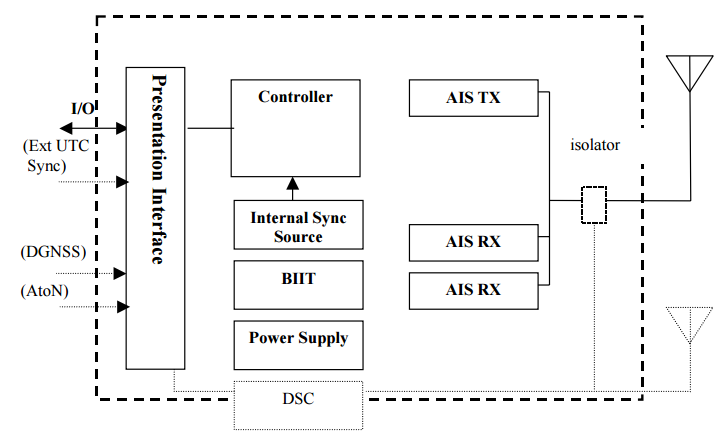
* + an agent of the AIS-SM to allow for configuration and monitoring of the AIS-PCU and AIS fixed station(s). In some cases all of this functionality can be rolled into one physical component.



1. Layered structure of AIS Service [1]

The following functional elements of the AIS base station are required (compulsory) in the minimum configuration of an AIS Base Station [1]:

* Two multi-channel receivers
* One multi-channel TDMA transmitter: Since the minimum configuration of the AIS base station comprises only one transmitter, the AIS base station (in its minimum configuration) cannot transmit on both VHF channels (AIS1 and AIS2) simultaneously.
* A controlling unit, managing the functions of all components of the AIS station. It manages the time slot selection process, the operation of the transmitters and receivers, the processing of the various input signals and the subsequent distribution of all of the output and input signals to the various interface plugs and sockets, and the processing of messages into suitable transmission packets. According to this, the controlling unit is in charge of converting the DGNSS corrections retrieved in RTCM format into the VDL Message type 17 format (excluding the preamble and parity fields).
* An internal sync source which may also be used as a position sensor for the AIS base station.
* A Built-In-Integrity-Test unit (BIIT) controls continuously integrity and the operation of the unit.
* A power supply
* A Presentation Interface (PI): The Presentation Interface allows the output of data from the AIS base station to the physical shore station and to input data to the AIS base station. The PI also allows for input of DGNSS corrections for transmission by the AIS base station if provided in the PI message format.



1. Functional block diagram of an AIS base [1]

The following functional elements are optional to the AIS base station:

* Additional receiver(s).
* Additional transmitter.
* DSC functionality.
* **Input of DGNSS corrections by a dedicated input port**.
* The AIS base station may contain a functionality to transmit Aids-to-Navigation VDL messages (on behalf of physically existing AtoNs or as pseudo AtoN’s).

1. DGNSS Correction Transmission via AIS
   1. Introduction

First, it is necessary to emphasize that the provision of DGNSS corrections via AIS VDL message #17 is not mandatory. It is an additional service that may be provided by the local competent authority.

For Class A shipborne AIS stations, it is not mandatory to include an internal GNSS receiver, which conforms to the applicable requirements of IMO and IEC for position sensors. However, market surveys show that virtually all Class A shipborne AIS stations include such an internal GNSS receiver and are thus able to use a differential corrected position for position reporting, when correction data is available [1].

As opposed to Class A, for Class B shipborne AIS stations, the provision of an internal GNSS receiver is required because the provision of a quality position from an external position sensor to the Class B shipborne AIS station cannot be assumed.

Therefore, given that virtually, all Class A and Class B devices are equipped with an internal GNSS receiver, broadcasting differential GNSS corrections from an AIS shore station on the AIS VDL channel, enables all vessel-mounted AIS receivers to navigate and to report with differential accuracy.

On the other hand, it is noted that the DGNSS corrections to be transmitted by AIS (via message 17) can be obtained from a MF beacon system (via radio or via communication lines) or from a dedicated reference station, which could be used to feed one or multiple AIS stations [1].

The information presented in this paper focuses on the second case, that is, the corrections are not obtained from a MF beacon but specifically generated to feed the AIS service. To this regard, it is noted that IALA recommends [1] to provide these corrections to the same integrity standard as for the IALA DGNSS beacons.

* + 1. Decentralised Solution

One alternative for the transmission of DGNSS corrections via AIS is to generate locally the message type 17 by connecting a DGNSS reference station to the AIS base station.

When AIS Base station is in independent mode it may broadcast DGNSS corrections received via a dedicated port (see Figure 2). It is noted that the preamble and parity (fields included in the RTCM message) shall be discarded by AIS Base station before transmitting Message 17.

Apart from the compulsory elements described above, the AIS Base station shall also include a DGNSS reference station, for the generation of the corrections and a monitoring station, for the integrity check.

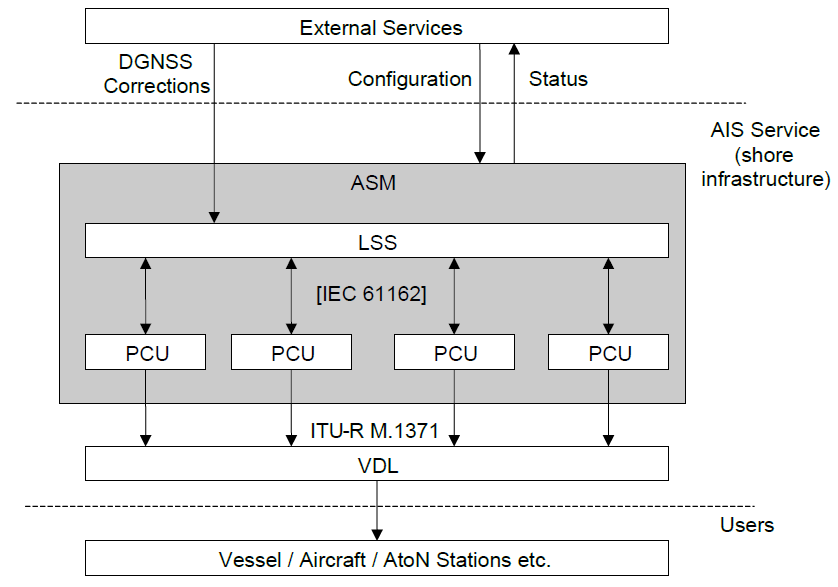
It is to be noted that the integrity monitoring check is recommended for the transmission of DGNSS corrections via AIS [2]. In case the DGNSS corrections are obtained from an IALA Beacon, the integrity of the corrections is already checked by the reference station. However, in case a dedicated station is deployed, local integrity monitoring is required: “any stand-alone DGNSS reference station used by an AIS shore-station would need integrity monitoring” [1].

* + 1. Centralised Solution

Another option for the provision of DGNSS corrections via AIS is to generate the message type 17 in a central facility (ASM) and distribute it to the different AIS base stations.

The DGNSS corrections being provided to the AIS Service are in a data format defined by RTCM SC-104. The DGNSS correction data is encapsulated in an IEC 61162 VDM sentence (discarding the preamble and parity fields) by the AIS Logical Shore Station (AIS-LSS) for processing by the AIS PSS Controlling Unit (AIS-PCU). The AIS-LSS ensures that the latest full set of corrections is used, and that they are transmitted at the correct time.

The AIS-LSS also prioritises the DGNSS corrections so that any new integrity alarms that have been identified by the DGNSS corrections source are transmitted in the next Message 17 slot(s) [2] (ensuring the 10-second TTA requirement).

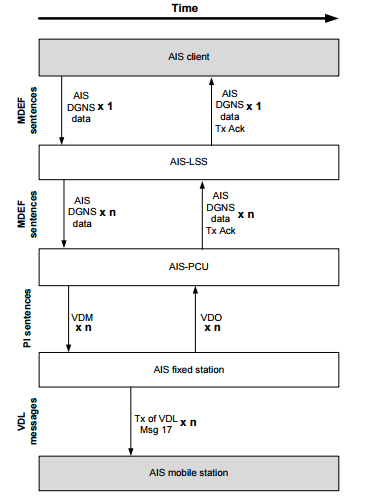


1. AIS DGNSS Corrections: Centralised solution

The DGNSS data will usually be sent from the external service to the AIS-LSS but could also be sent from the ASM directly to the AIS-PCU if the ASM supports the management of DGNSS corrections.

In case the DGNSS data is to be transmitted by more than one AIS-PCU, the responsible for duplicating and routing the DGNSS corrections to each AIS-PCU is the AIS-LSS. Therefore, in case of transmitting the same corrections via multiple AIS stations, the AIS-LSS will duplicate and route the DGNSS data to each AIS-PCU. Otherwise, if the DGNSS corrections are customised for each AIS stations, the AIS-LSS will route the DGNSS corrections to the appropriate AIS-PCU.

The AIS base station(s) will produce a message confirming that the VDL message 17 was indeed broadcasted [3].



1. Interaction & data flow model for external BAS DGNS\_COR [3]
2. High level architecture of an EGNOS based DGNSS service over AIS

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

Two system architecture options are considered for the provision of EGNOS corrections over AIS:

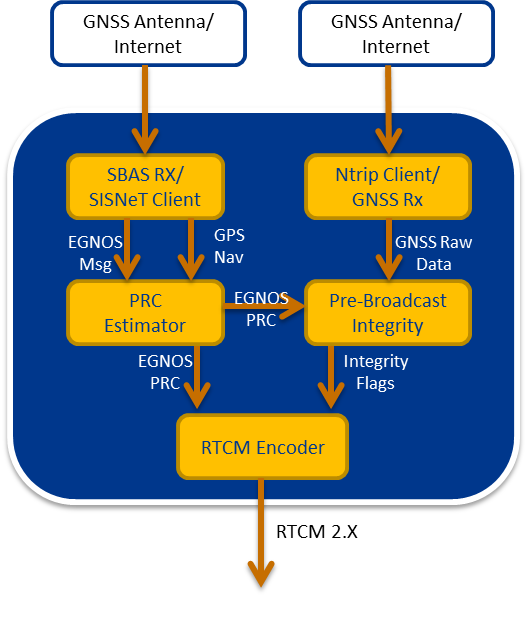
* EGNOS based DGNSS solution over decentralised AIS service
* EGNOS based DGNSS solution over centralised AIS service
  1. EGNOS based DGNSS solution over decentralised AIS service

In this case, the source for the generation of the DGPS corrections to be broadcast by the AIS station is the EGNOS message (either obtained from the EGNOS SIS or from the EDAS SISNeT service).

As depicted in Figure 2, the DGNSS corrections are provided as input (via a dedicated port) to the AIS Base Station, therefore, whether these corrections are received from a traditional DGNSS stations or generated based on EGNOS, is completely transparent for the AIS Base Station. Taking this into account, it is not necessary to do any change on the AIS Base Station but only on the external reference station and Integrity Monitoring (RS & IM). The external RS shall be replaced by a RS software to produce the differential GPS correction taking the SBAS messages as input. This component would basically consist of an RTCA to RTCM converter. A pre-broadcast integrity monitoring concept could be implemented to check the integrity of the differential corrections generated by the EGNOS based RS.

A block diagram of the resulting RS & IM, including both HW and SW components is included hereafter. It is to be noted that the SBAS message and the GPS ephemeris can be obtained from an SBAS enabled receiver or from the EDAS SISNeT service over the internet. Regarding the GNSS raw data needed to check integrity of the corrections, this data could be obtained from a dedicated GNSS receiver or from one of the different networks of receivers available (via internet/Ntrip).

Also, in case of using an SBAS enabled receiver to obtain the EGNOS message (instead of the EDAS SISNeT service), it could be considered to use the GNSS observations collected by this receiver to check the integrity of the data (note that the observations are not used to generate the differential corrections).



1. EGNOS based AIS station: RS & IM block diagram

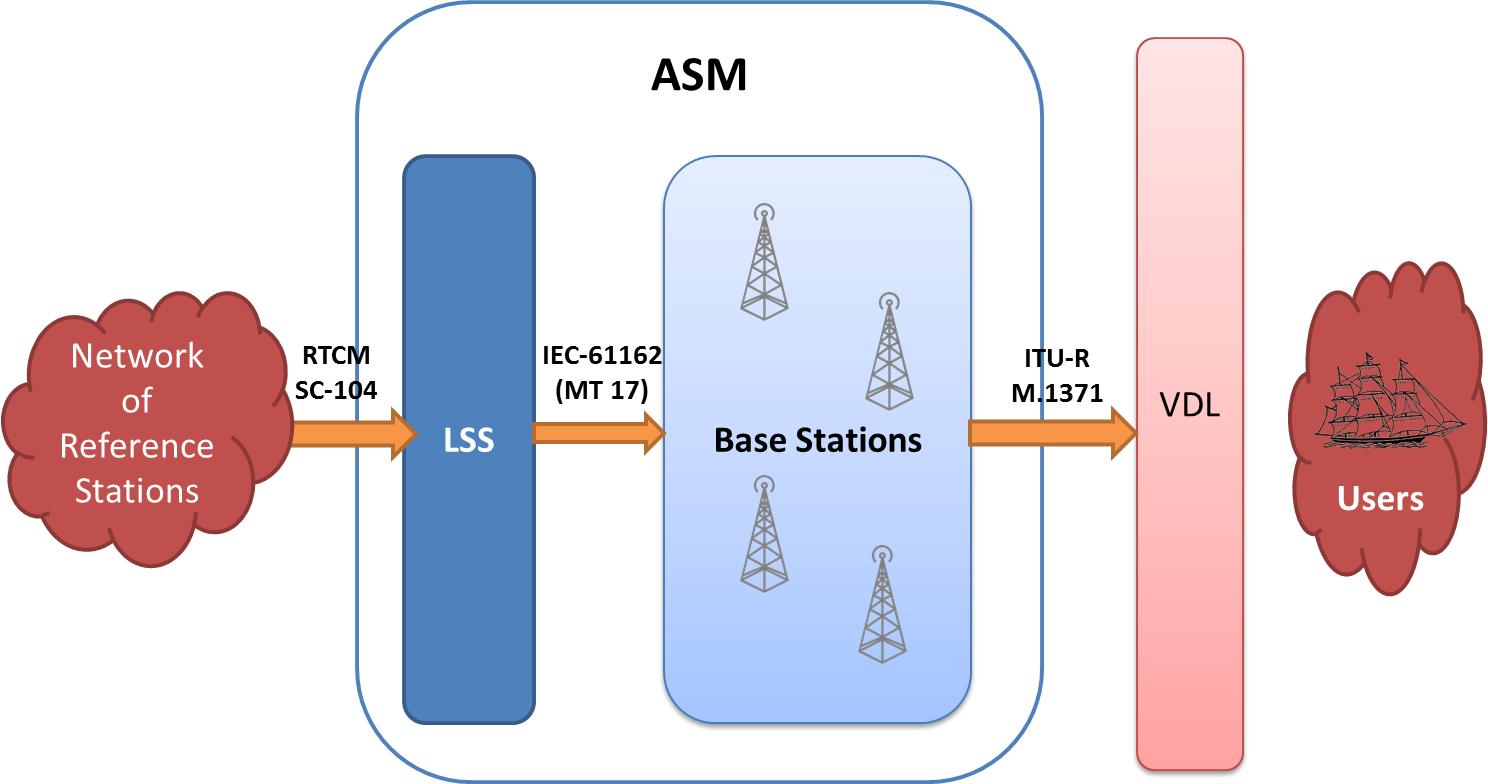
The corrections generated will be provided to the AIS Controller Unit in RTCM format (via the dedicated input port – see Figure 2). Therefore, there will be no change with respect to the current interface, being the Controller Unit in charge of converting the RTCM message into VDL Message Type 17 format. As detailed above, it is important to remark that this solution is completely transparent for the base station itself, since it receives the corrections in RTCM format regardless they are generated by a traditional reference station or converted from the EGNOS message to RTCM format.

Finally, it is important to remark that the provision of DGNSS corrections is not a core functionality of the AIS system, just an optional message that could be transmitted through the MT17. Therefore, the VDL channel monitoring does not depend on the transmission or not of this message. For that reason, for the design of the architectures (decentralised and centralised) presented in this paper, the monitoring of the VDL channel has not been taken into account.

* 1. EGNOS based DGNSS solution over Centralised AIS service

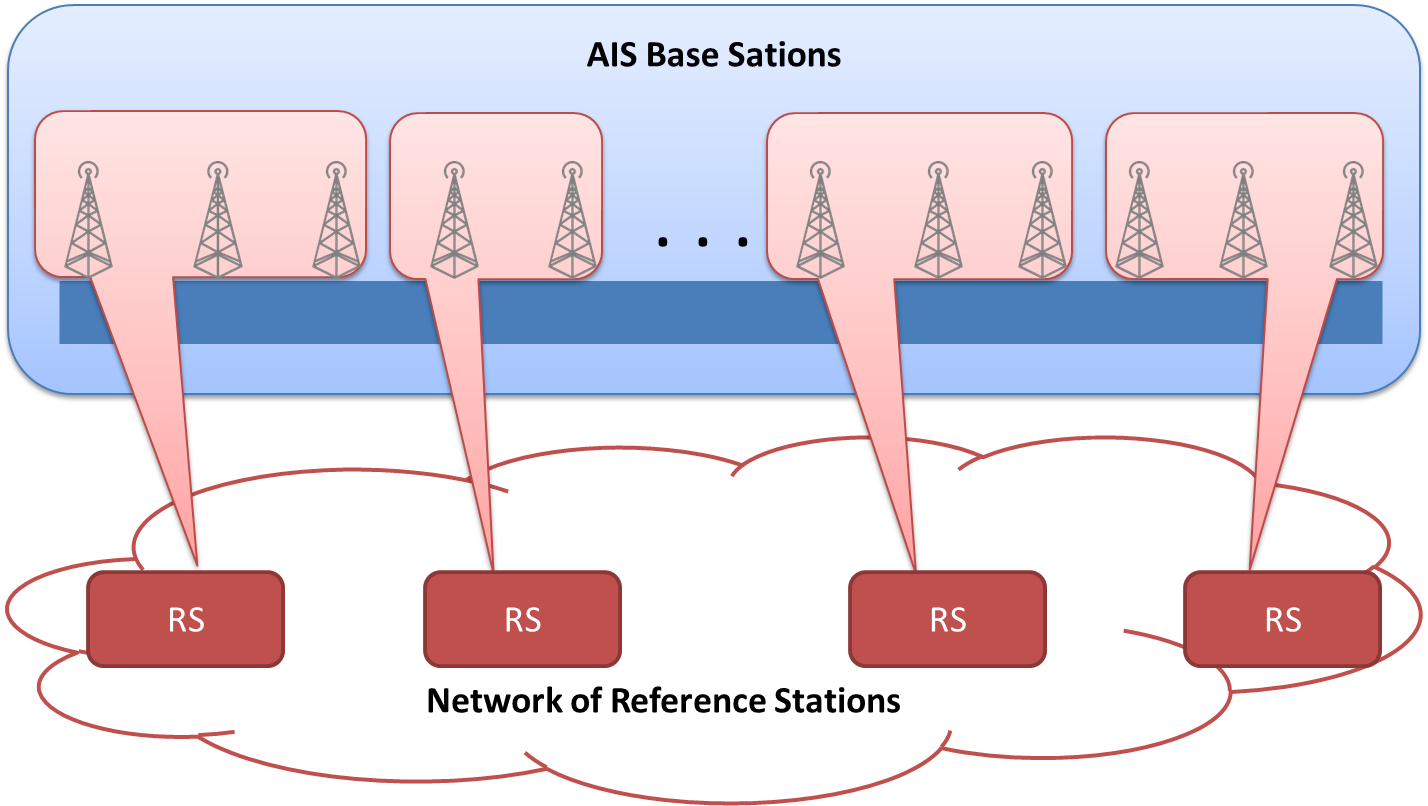
As it was mentioned before, although it is possible to generate the Message Type 17 in an “isolated” base station, the most common solution for the provision of DGNSS corrections via AIS is to generate the Message Type 17 in a central facility (ASM) and distribute it to the different AIS base stations.

As depicted in the following figure, the DGNSS correction data from the reference station(s) is encapsulated in an IEC 61162 VDM sentence (discarding the preamble and parity fields) by the AIS Logical Shore Station (AIS-LSS) for processing by the AIS PSS Controlling Unit (AIS-PCU). The Message Type 17 generated by the Logical Shore Station is then provided to each base station and finally transmitted to the users through the VDL channel.



1. Traditional DGNSS over AIS Centralised solution

Considering the short coverage of the AIS base stations (within LoS range), a set of base stations is normally distributed alongside rivers, canals, coast and ports to cover the whole service area. On the other hand, taking into account that the range of a DGNSS station is in the order of 200 NM, the corrections generated by a reference station are normally used to feed multiple AIS base stations. This means that the same DGNSS corrections are transmitted by several stations. This architecture is depicted in the following figure.



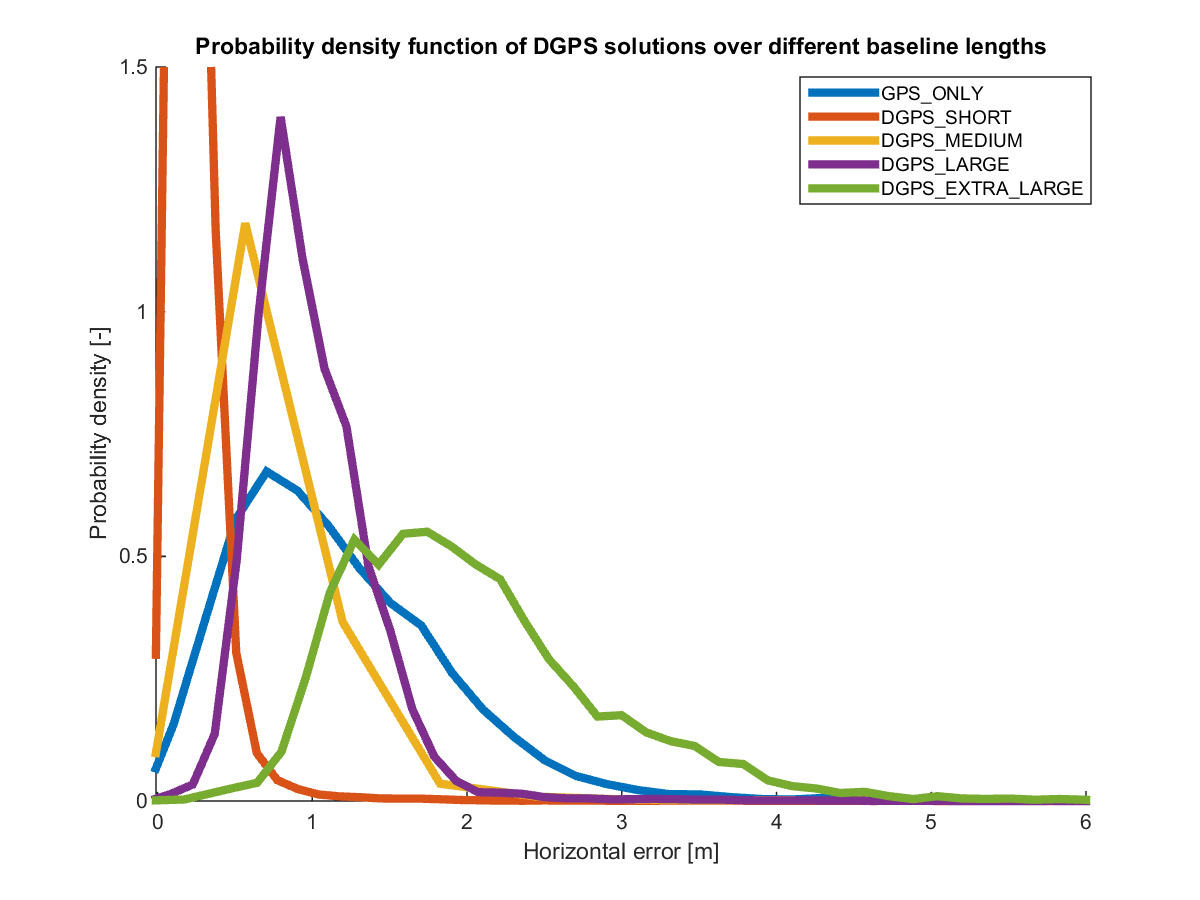
1. DGNSS over AIS Network Configuration

The fact that the same DGNSS corrections are transmitted by multiple stations and therefore, the limitation between the performances provided and the cost of having a dense network of reference stations, may be overcome by implementing and EGNOS based solution.

To illustrate the added value (in terms of accuracy performance) obtained by generating EGNOS DGNSS corrections for each AIS base station instead of feeding multiple stations with the same corrections, the results presented in the ION GNSS 2015 paper “EDAS (EGNOS Data Access Service): Alternative Source of Differential GPS Corrections for Maritime Users” [4] are included hereafter.

In this article, 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) was presented.

The following figure depicts the degradation of the DGNSS performances over different baseline lengths: short (<50km), medium (200-350km), large (350-500km), extra-large (800-1000 km).

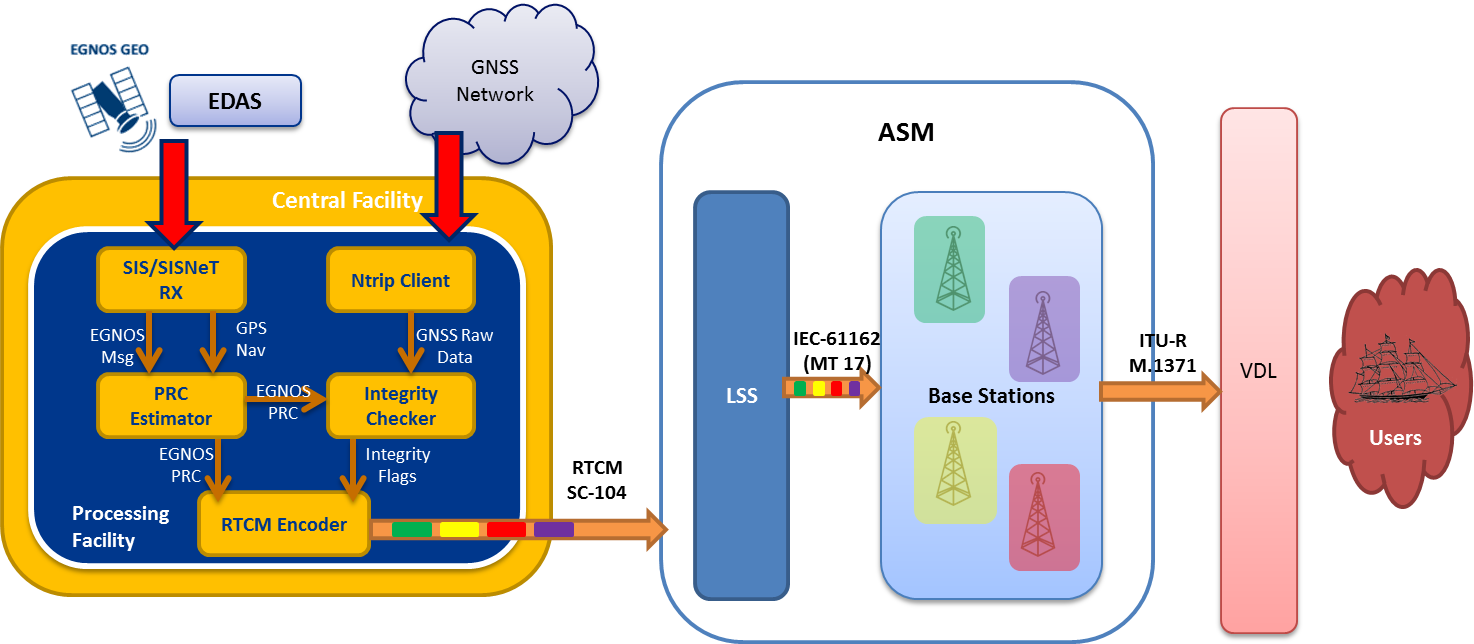


1. Probability density function of DGPS solutions over different baseline lengths[4]

The EGNOS corrections in RTCA format can be customized and converted into RTCM format for any location placed within the EGNOS service area. Therefore, it is possible to generate RTCM data streams customised for each AIS base station and therefore provide DGNSS corrections for short baseline lengths. In this way the accuracy performance could be improved in comparison with the traditional approach, in which the corrections generated by a reference station are used to feed multiple stations and therefore, the distance between the rover and the reference station (where the corrections are generated) can be much more larger.

At very high level, the architecture of this solution would consist on:

* **Central Facility (CF),** responsible for the generation of the PRC corrections (including integrity).
* **Monitoring Network,** providing GNSS data for the integrity monitoring check.
* **AIS Service Manager (ASM**), which retrieves the EGNOS corrections in RTCM and converts them in an IEC 61162 VDM sentence (discarding the preamble and parity fields) to be then distributed to the final users by the AIS base stations using the VDL channel.



1. EGNOS based DGNSS corrections over AIS architecture

A more detailed description of each of these components is provided below:

* **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.

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 near the beacon transmitters) or take advantage of the GNSS networks available.

* **Monitoring Network**

As detailed above, the Central Facility needs to have access to GPS measurements collected from a receiver located within the service area

One alternative is to have a dedicated GNSS receivers, capable of transmitting (via internet) the raw data collected to the Central Facility.

Another option is to get the GNSS raw data (used for the integrity monitoring) from one of the different networks of receivers available. The main disadvantage of this solution is that the Aton provider needs to rely on an external entity, so it would be necessary to establish a Service Level Agreement (SLA) to guarantee the reception of the data with the quality and availability required.

* **AIS Service Manager (ASM)**

The RTCM corrections generated by the central facility are transmitted to the AIS Service Manager which converts them in an IEC 61162 VDM sentence (discarding the preamble and parity fields) to be then distributed to the final users by the AIS base stations using the VDL channel.

It is important to remark that this component does not need to be modified with respect to a traditional DGNSS solution. All the inputs/outputs are the same and in the same format, therefore, no change is required. This means that the fact that the RTCM corrections are generated based on the EGNOS message or by a traditional DGNSS reference station is completely transparent for the ASM.

1. Conclusion

Two alternatives for the provision of EGNOS corrections via AIS have been analysed:

* EGNOS based DGNSS solution over decentralised AIS service
* EGNOS based DGNSS solution over centralised AIS service

The alternative to be considered would depend on the AIS existing infrastructure as well as the type of service provided. For instance, the decentralised architecture could be suitable in harbours, where the harbour authority is the one controlling the AIS service. However, if the AIS service is supported and approved by the National Maritime Authority, then the centralised solution could be more appropriate.

It is to be noted that, in both cases (decentralised and centralised), the provision of EGNOS corrections via AIS is completely transparent to the AIS Base Station. In the decentralised architecture, the corrections are generated by an external component that receives the EGNOS messages and GPS ephemeris from EDAS or the EGNOS SIS, and converts these corrections into RTCM format. The EGNOS based DGNSS corrections feed the AIS base station via a dedicated port. The decentralised architecture, could be useful for instance in harbours, where the harbour is controlling the AIS service.

In the centralised architecture, the DGNSS corrections to be transmitted via AIS (message type 17) are generated in a central facility (ASM) and distribute it to the different AIS base stations. In this architecture, the main difference with respect to a traditional DGNSS solution is that instead of receiving the corrections from a DGNSS reference station, the pseudorange corrections are computed based on the EGNOS message and customised for each AIS base station.

To this regard it is noted that an EGNOS based solution can provide and added value both in terms of cost reduction and accuracy performance improvement. The integration of EGNOS on an AIS centralised solution can reduce the cost of deploying DGNSS reference station alongside rivers, canals, coast and ports to cover the whole service area.

On the other hand, as detailed in the previous section, the fact that the EGNOS based DGNSS solution can be customised for any desired location and therefore for each AIS base stations, could improve the accuracy performance in comparison with the traditional approach, in which the corrections generated by a reference station are used to feed multiple stations and therefore, the distance between the rover and the reference station (where the corrections are generated) can be much more larger.

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