Message exchange for flow management in maritime traffic management systems.

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Abstract

This paper introduces the concept of *flow management* in relation to traffic coordination and management in the maritime world. It defines the need for message exchange between vessels and shore-based coordination centers to accomplish optimal flow of vessels in narrow waters.

Existing message types in communication via the AIS and Maritime Cloud protocols are examined to be reused for the purpose, and where these are found inadequate new message types are proposed.

In order to take advantage of previous lessons learned, literature on the subject is studied and a number of design criteria for new messages are extracted. All proposed new message types are validated against these design criteria.

The paper is concluded by a complete set of detailed proposed message specifications to support flow management.

Chapter 1. Introduction

As part of — and as a contribution to — the MONA LISA 2.0 [MONALISA2] project, the Danish Maritime Authority has worked to define message conversation scenarios and detailed message formats for *flow management* in the context of *sea traffic management (STM)* as defined by [ARCH].

The results contain inputs, contributions, and insights from DMA and project partners.

This paper documents the process and the results, by

1. defining the domain problem,
2. setting the scope of work,
3. establishing design criteria,
4. proposing message conversation scenarios,
5. defining message formats in different formats,
6. validating message formats against design criteria,
7. introducing a reference implementation for AIS using application specific messages, and by
8. supplying test data to validate correctness.

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1.1. Problem definition

1.1.1. Flow management

As defined by [ARCH] flow management is communication which takes place between ships in a peer-to-peer situation, or between ships and a coordinating organisation (denoted STCC in this document, similar to a VTS conducting some level of service similar to Traffic Organisation Service) in order to:

1. Increase safety and prevent delays through a good flow in narrow channels with high traffic density.

2. Support vessel in arriving at final destination in due time as efficient as possible.

3. Provide information to interested parties about planned and predicted time of arrival to final destination or other point of interest.

For item 1 the term "good" means that collisions and dangerous situations are avoided and that vessels can safely follow their announced tactical voyageplan through the area.

Flow *management* is based on knowledge of vessels' tactical voyageplans; i.e. announcements from each vessel regarding their intended manouvers in the immediate short-term future. When this knowledge is known either centrally at a coordinating center or distributed between nearby vessels, it is possible for a vessel to better understand the intentions of other nearby vessels and adjust own tactical route to achieve better flow, or for the coordination centre to suggest adjustments to tactical route, with the purpose of obtaining a "good" overall flow. This process is called *flow management*.

If flow management takes place in a self-organizing manner between vessels on a peer-to-peer basis it is called *autonomous flow management*. When a coordinating center is performing it the process is called *controlled flow management*. In a fully managed scenario — whether autonomous or controlled — the risk of situations escalating to a level that require the application of collision avoidance regulations can be minimized.

Tactical voyageplan

In order to facilitate flow management vessels in the area must broadcast their tactical voyageplan and optionally basic information concerning their manouvering capabilities, such as turning radius.

Flow management suggestion

A suggested change to a tactical voyageplan is called a *flow management suggestion*. It can take one of two principal forms:

1. Geometry-based (adding, deleting or changing waypoints)

2. Speed-based (not changing any waypoints)

Changing the geometry of an tactical voyageplan is a relatively complex operation for the vessel’s navigator. Among other things the process involves a safety check of the new route and reprogramming of navigational equipment. The cost/workload of this operation reduces the likelihood of a vessel complying with suggested changes.

Changing the vessel’s speed (or waypoint ETA’s) is a far simpler operation for the navigator. This involves only adjustment of the vessel’s speed. It is therefore expected, that the likelihood of a of vessel complying with a suggested change of this type is higher than suggested changes to geometry.

1.1.2. Controlled flow management

Controlled flow management always takes place inside a defined geographical area called the *controlled area*. The controlled area is a closed polygon.

Vessels can be located inside the controlled area — or outside the controlled area.

Vessels outside the controlled area can be in state

- *entering* — meaning that the vessel intends to enter the controlled area.

Vessels inside the controlled area can be in states

- *leaving* — meaning that the vessel intends to leave the controlled area.
- *staying* — meaning that the vessel intends to seek berth, drop anchor, or elsehow keep manouvering inside the area.

Some of the vessels are aware of some of the other vessels' tactical voyageplans, and the coordination centre is aware of some of the vessel's tactical voyageplans.

As any coordinating organization the coordination centre is continuously receiving an AIS data stream, including type 1-3 position messages and type 5 ship and static voyage messages, so that it can maintain an updated real-time picture of the current traffic situation.

As part of [ARCH] vessels are also required to publish their Dynamic Voyage Plan to STCC when it has been changed and safety checked.

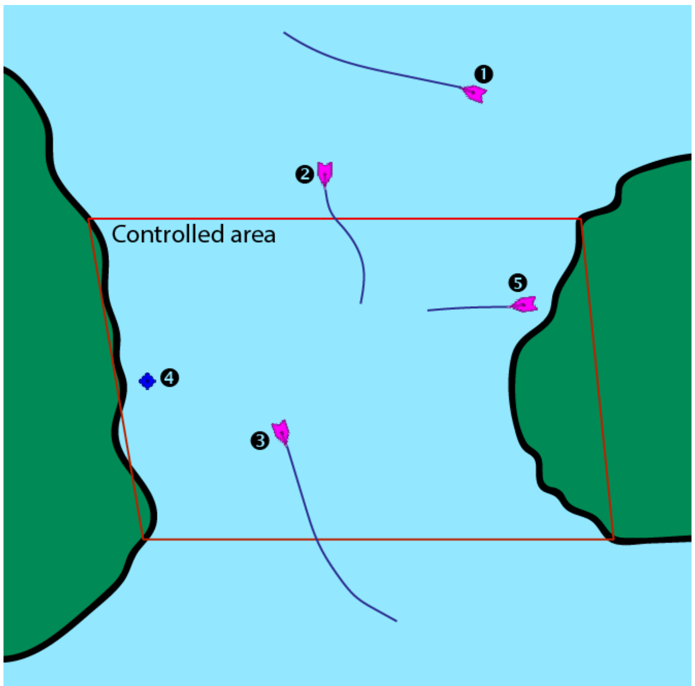

Figure 1. A controlled area and five vessels showing their intended routes. There are vessels outside (1, 2) and vessels inside (3-5) the controlled area. A vessel (2) is entering, a vessel is leaving (3), and two vessels are staying (4 ,5).

1.1.3. Autonomous flow management

It has previously been observed in simulator trials, that given the information about the more detailed intentions of other vessels, and the ability to express own tactical plan to peer vessels, navigators quickly adapt to utilizing this mechanism, to clearly express own intention in a narrow passage situation.

Autonomous flow management is thus anticipated to evolve out of the availability of information, that enable navigation systems to better predict realistic CPA and TCPA values and pinpoint likely critical passages at larger distances and longer timewindows, based on sharing the information on the tactical routes of peer vessels.

1.1.4. Maritime Cloud

The Maritime Cloud [MARCLOUD] is defined as “A communication framework enabling efficient, secure, reliable and seamless electronic information exchange between all authorized maritime stakeholders across available communication systems” and contains

1. A Maritime Identify Registry

2. A Maritime Service Portfolio Registry

3. A Maritime Messaging Service (MMS)

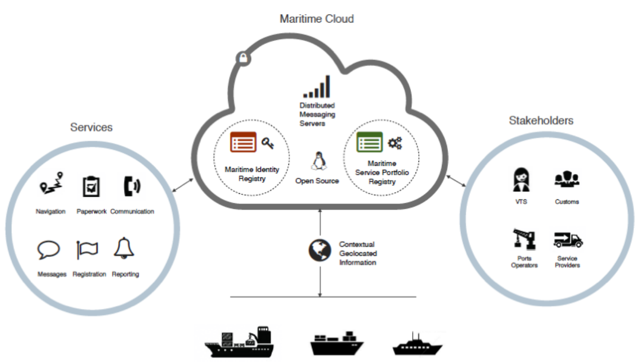

Figure 2. The Maritime Messaging Service enable vessels and stakeholders to provide services in a secure exchange

Vessels, STCC and other stakeholders may enable a service by providing an *endpoint* which can be queried. Requests may be initiated from any stakeholder by invocation of the *endpoint*.

Vessels, STCC and other stakeholders may also choose to *broadcast* a set of messages. Messages may be geo-located to a specific area.

Service endpoints and broadcast messages are described in a specific Maritime Service Descriptor Language (MSDL).

1.2. Scope of work

The scope of the work in this paper is *controlled flow management in a limited area (in order of size as a VTS area) based on flow management suggestions in the speed-based form*.

Use cases will be used to describe the events and actions of conversations (information exchange) that could support a flow management scenario.

Design criteria and specific design proposals will be described for messages and conversation sequences, first in generic terms, independant of data transport mechanism, later in specific terms related to utilizing AIS as the communication channel and the Maritime Messaging Service in the Maritime Cloud taking into account the specific limitations of the transport channel.

Chapter 2. Use cases

Given the transmission media there are two sets of use cases depending on the choice of either AIS or MMS based messaging

2.1. Use case (AIS-1): Vessel enters the controlled area

Table 1. Use case.

No.	Event	Action
1	The coordination centre detects, that a vessel has entered the controlled area.	The control centre transmits an addressed message to the vessel requesting it broadcast tactical voyageplans. [This is done even if the coordination centre already has this information in order to distribute this information to other vessels in the area.]
2	The vessel receives the message.	The vessel responds by broadcasting a message containing its tactical voyageplan.
3	The broadcast is received by the coordination centre (and likely some of the other vessels in the area).	The control centre recalculates optimal speeds per vessel. [with priority to suggest speed changes for V_0 over other vessels, and fewest possible other vessels, and only for vessels intending to leave A.]
	Exception: The broadcast is never received by the coordination centre.	The coordination centre retransmits its message to the vessel.
4	The coordination centre's recalculation of optimal speeds completes.	The coordination centre transmits an addressed messages with flow management suggestion s to those vessels which (according to the calculation) require changes.
5	A vessel receives its flow management suggestion from the coordination centre.	The navigator is alerted.
	Exception: The flow management suggestion is never received by the vessel.	*May lead to special case: Coordination centre discovers new suggestions needed.*
6	Navigator of approves flow management suggestion .	The vessel broadcasts a message containing its new tactical voyageplan.

2.2. Use case (AIS-2): Coordination centre determines new flow management suggestion s needed

Table 2. Use case.

No.	Event	Action
1	The coordination centre detects that the current flow is not optimal ("good")	The control centre recalculates optimal speeds per vessel.
2	The coordination centre’s recalculation of optimal speeds completes.	The coordination centre transmits an addressed messages with flow management suggestion s to those vessels which (according to the calculation) require changes.
3	A vessel receives its flow management suggestion from the coordination centre.	The navigator is alerted.
	Exception: The flow management suggestion is never received (or is ignored) by the vessel.	*May lead to special case: Coordination centre discovers new suggestions needed.*
4	Navigator of approves flow management suggestion .	The vessel broadcasts a message containing its new tactical voyageplan.

2.3. Use case (AIS-3): Vessel autonomously broadcasts its tactical voyageplan

Table 3. Use case.

No.	Event	Action
1	Due to some event (examples: A recurring period expiring, a change to the current tactical voyageplan or expiration of a previously broadcasted tactical voyageplan) a vessel decides to broadcast its tactical voyageplan.	The vessel broadcasts a message containing its tactical voyageplan.

No.	Event	Action
2	Other vessels receive the message.	The receiving vessel(s) may decide to change their intended manouvers based on knowledge of the transmitting vessels tactical voyageplan.
	A coordination center receives the message.	The coordination center engages into Use case (AIS-2): Coordination centre determines new flow management suggestion s needed.

2.4. Use case (AIS-4): Vessel cancels its tactical voyageplan

Table 4. Use case.

No.	Event	Action
1	The navigator of a vessel decides to cancel a previously broadcasted tactical voyageplan.	The vessel broadcasts a message containing cancellation of tactical voyageplan.
2	Other vessels receive the message.	The receiving vessel(s) may decide to change their intended manouvers based on knowledge of the transmitting vessels tactical voyageplan. They may engage into Use case (AIS-3): Vessel autonomously broadcasts its tactical voyageplan.
	A coordination center receives the message.	The coordination center engages into Use case (AIS-2): Coordination centre determines new flow management suggestion s needed.

2.5. Use case (AIS-5): A vessel inquiries about the tactical voyageplan of another vessel

Table 5. Use case.

No.	Event	Action
1	The navigator of a vessel, V_L, determines, that either a) has he never received the tactical voyageplan of another vessel [This could happen in case of e.g. radio conditions in an area being so that *some* (but not all) vessels fail to receive broadcasts from some other vessels.], V_R, or b) the observed manouvers of V_R deviate from the last received tactical voaygeplan from V_R	The navigator of V_L orders transmission of a voyageplan inquiry addressed to V_R.
2	V_R receives the message.	Automatically - or based on navigator actions - V_R broadcasts a message carrying its tactical voyageplan.
3	Other vessels, including V_L, receive the message.	The receiving vessel(s) may decide to change their intended manouvers based on knowledge of the transmitting vessels tactical voyageplan. They may engage into Use case (AIS-3): Vessel autonomously broadcasts its tactical voyageplan.
	A coordination center receives the message.	The coordination center engages into Use case (AIS-2): Coordination centre determines new flow management suggestion s needed.

2.6. Use case (MMS-6): Requesting a tactical voyage plan

Table 6. Use case.

No.	Action
1	The STCC detects that a vessel approaches or has already entered the controlled area.
2	The vessel receives a request for a tactical voyage plan. The request specifies the time interval of the tactical voyage plan as a configurable time window (Default five hours).
3	The vessel check that it wish to communicate the tactical voyage plan with the requestor.
4	The vessel responds with a tactical voyage plan.
Exception	Requestor may not be a coordination centre. Vessel may choose not to disclose the tactical voyage plan.
Exception	The vessel may not have a tactical voyage plan at present.

2.7. Use case (MMS-7): Vessel receive flow management suggestion

No.	Action
1	The vessel receive a flow management suggestion from the coordination centre.
2	The vessel acknowledge the receipt of the suggestion.
3	The officer on watch (OOW) verify the proposal.
4	If the vessel accepts the proposal:
	— The vessel update the dynamic voyage plan if needed. Any changes to the route or schedule will result in an update being sent to the STCC.
	— The vessel respond with approval message.
	— The vessel starts broadcasting new tactical voyage plan via AIS.
5	If the vessel does not accept the proposal:
	— The vessel respond with a rejection message.
Exception	The vessel do not respond to the flow management suggestion.

Chapter 3. Design criteria

Messaging in the maritime domain has been available many years and communication standards have evolved and been added and augmented several times to accomodate the increasing demand for handling more and more complex scenarios in the maritime domain.

When suggesting message exchange for advanced use cases, such as for flow management, we want to take lessons learned from the past years into account. Literature, such as [TOILS], has therefore been studied to establish a set of design criteria for the messages that are defined for flow management.

In section Validation against design criteria it will be validated, that the suggested messages layouts and payloads are in compliance with these design criteria.

3.1. General design criteria

3.1.1. Design with the end-user in mind

In accordance with [ARCH], §3, all systems shall be designed with the end user (e.g. mariner, ship owner, operator), in mind.

> This shall be achieved, by carefully identifying and defining use cases expressed in user domain terms and approved by user domain experts (such as navigators) before the actual design of message conversations and message layouts takes place. And by validating that the detailed message designs support the defined use cases.

3.1.2. Design for multivendor environment

In accordance with [ARCH], §3 p.6, one of the main goals (here interpreted as *design criteria*) of the MONALISA 2.0 project is to "achieve full and seamless interoperability of systems in Sea Traffic Management (STM) [...] in a multi-vendor environment".

> This shall be achieved by ensuring that relevant stakeholders in government and industry can contribute to and review the design of conversations and messages in flow management.

3.1.3. Information transfer involving ships must be bandwidth efficient

In accordance with [ARCH], §7 p.23, information transfer involving ships must be highly bandwidth efficient.

This shall be achieved by designing messages to be as compact as possible, avoiding redundant information in message layouts, and using bit-level compression where applicable and possible.

3.1.4. Interactions must be robust

In accordance with [ARCH], §7 p.23, ship-shore interactions must be robust to unstable, changing, high latency links.

This shall be achieved by designing conversation for robustness - supplement a repetitive broadcast regime with a request/response mechanism, which is activated when a user (ship or shorebased) actively investigates a particular ships intentions, in case the latest revieved broadcast is not sufficiently recent.

If the data transport mechanism supports transport layer acknowledgements, the request/response mechanism can be safeguarded against a message transmission being lost through utilizing these acknowledgement mechanisms.

3.1.5. Ship-shore data IP connections must be initiated from ship

In accordance with [ARCH], §7 p.23, ship-shore data connections must be initiated from ship, to address cyber security.

This shall be achieved by designing the required mechanisms of communication, such that ship-to-shore communication is based on IP-based connection-oriented communication (e.g. TCP/IP), then such a connection can only be initiated from the ship-side.

3.1.6. Indication of trust

When utilizing AIS, anyone can spoof the identity of a ship and interact with others. If utilizing the Maritime Messaging Service — or some other transport mechanism that offer mechanisms for secure data transport — the authenticity and integrity of the information exchanged could possibly be guaranteed.

It is important to a navigator or STCC to be able to determine the security level of the information provided.

This shall be achived by designing the user interface of the receiving party to indicate the level of trust that can be associated with the sender.

3.2. AIS-specific design criteria

3.2.1. Consider updated definitions of ASM and related guidance, before developing new ASM;

In accordance with [IALA144], recommendation 4, IALA recommends that members make use of the IALA ASM collection [AISASM] by taking into account other updated definitions of ASM and related guidance, before developing new or implementing the use of existing Regional ASM.

> This shall be achieved by consulting the ASM collection [AISASM] to ensure that no other existing ASM already fulfills the requirements of any newly designed message before it is submitted for approval.

3.2.2. Contribute to the IALA AIS ASM collection

In accordance with [IALA144], recommendation 6, members are recommended to contribute to the IALA ASM collection through their National IALA Member.

> This shall be achieved by ensuring that the final and agreed ASM messages to support flow management are submitted to the IALA ASM collection by the national IALA member, in this case the Danish Maritime Authority.

3.2.3. Low transmission frequency

In accordance with [IMOSN289], §3.3, the frequency of message transmission should be limited in order to prevent system overload.

> This shall be achieved by careful design of the criteria which trigger a message transmission, in order to minimise the number of transmissions to the lowest possible.

3.2.4. Limit no. of VHF transmission slots

In accordance with [IMOSN289], §3.4, AIS messages occupying more than three (3) slots should be avoided, unless there is a low load on the VDL or a compelling reason to do so.

> This shall be achieved by designing messages to avoid occupying more than 3 slots.

3.2.5. Use 6-bit ASCII

As pointed out by [TOILS] the decision to use 6-bit ASCII encoding in AIS messages is a *blunder*. But as it states: "Some major defects, such as the handling of string data, are too deeply embedded to be removed". Thus in the design of new messages, the 6-bit encoding scheme will be maintained to avoid further complexity to [AISSPEC5] and related recommendations and guidelines.

This case is an example of a design blunder, where one possible remedy — which could promote good quality software — would be the existence of open source reference implementations of 6-bit ASCII encoding/decoding functions in different programming languages, as a shared, well tested resource.

> This shall be achieved by designing string fields of new messages to use the 6-bit character encoding scheme defined by [AISSPEC5] annex 8.

3.2.6. Fixed length messages

By experience and in accordance with [TOILS], "types 1 through 4: Fixed-length felicity", fixed-length messages are simple to parse and can be regarded as one production in the message *grammar*. [TOILS] further states, that "from a reliability-engineering point of view, this [fixed-length messages] is a best case scenario".

> This shall be achived by designing any new messages, so that they have fixed bit-length and fixed field-offsets, unless there are important and documented reasons why this cannot be achieved.

3.2.7. Fixed bit-offset for fields

[TOILS], "Ways forward for AIS", recommends to avoid fields with variable offsets.

> This shall be achieved by designing new ASMs to have fixed bit-length for each data field to ensure that each data fields starts at a fixed bit-offset.

3.2.8. Variable fields last

According to [TOILS], "Drawing lessons from the defects", it is a minor defect not to have variable-length fields be the last in the message (such as the variable-length binary payload in message type 26 followed by a radio-status field). Variable-length fieds should first and foremost be avoided. And if, for compelling reasons, they cannot - they should be transmitted last in the message to preserve fixed-offset for as many data fields as possible.

This shall be achieved by designing new ASMs so that any variable-length data fields are at the end of the message.

3.2.9. One dispatch field

[TOILS] states in several places that the no. of protocol extension mechanisms should be minimal and preferably limited to 1. Any *dispatch fields* used to control message variants (such as the message type field), should precede any of the data fields it controls.

This shall be achieved by designing new ASMs so that no new extension mechanisms are introdued, to use a minimal no. of dispatch fields, and take dispatch fields into use in the following order: Message ID, Application Identifier, Message-specific dispatch.

3.2.10. Minimum no. of datatypes

[TOILS] states that good practice is "for there to be just one type per natural kind; e.g. in a geolocation protocol all longitudes should be encoded with the same length, signedness, and special values. Ditto all latitudes, bearings, timestamp fields, etc.". This also holds for the encoding of numeric values [Such as e.g. the "Rate of Turn field in the Common Navigation Block required taking a (sign-preserving) square root and then scaling" - which is different from all other numeric fields.] and the indication of non-existent values in order to avoid complicating exception and variants.

This shall be achieved by designing new ASMs so that they do not introduce any unnecessart new data type or encodings, and so that they (re-)use the most common and widely used type encoding used elsewhere in [AISSPEC5].

3.2.11. Single point of truth

[TOILS] recommends, based on lessons learned from message types 6 and 8, that messages should obey the "single point of truth" principle. This means that there should be no information redundancy inherint in the message, and that one piece of information can only be deduced from a single source in the message.

This shall be achieved by designing new ASMs so that no piece of information is redundant with other information in the same message.

3.2.12. Support stream-based parsers

[TOILS] recommends, based on lessons learned from message type 22, that in order to preserve memory and reduce decoder complexity, stream-based decoders must be supported by the message layouts. I.e. decoders which can decode incoming messages without looking ahead in the bit stream.

> This shall be achieved by designing new ASMs so that any dispatch-field, changing the interpretation of the message, is transmitted *before* the data fields whose interpretation it influences.

3.2.13. Don't split data fields across datagrams

As pointed out by [TOILS] some AIS messages, such as type 24, need to be reconstructed from two individually transmitted datagrams. This increases decoder complexity by requiring it to hold state between datagrams - and it adds a new dimension to the set of edge cases and problem scenarios, that must be foreseen. Therefore messages split across multiple datagrams must be avoided and all datagrams must be independent.

> This shall be achieved be designing any new ASMs to that their entire state is communicated in a single datagram.

3.2.14. Check design using ASN.1

[TOILS], "Drawing lessons from the implementations", recommends "that application-protocol designers should, as a routine part of their process, render the design as a specification in [ASN.1] or [BDEC]."

> This shall be achieved by supplying ASN.1 notation for each new ASM proposed.

3.2.15. Provide a reference implementation

[TOILS], "Drawing lessons from the implementations", recommends to "do a reference implementation before you publish an application protocol as a standard" and "as a best practice, the reference implementation should be open source".

> This shall be achieved by developing an open source reference implementation of a decoder for each proposed ASM. This reference implementation must be able to decode all variants of the ASM and should be developed before the protocol is published as a standard.

3.2.16. Provide test data sets for all message variants

[TOILS], "Drawing lessons from the implementations", recommends that "an example binary datagram in each of every possible variation of message shape together with a textual, human-readable decode of that datagram" is supplied to enable test and validation of decoders.

This shall be achieved by supplying example datagrams together with a human-readable decode of that datagram for each message variant.

Chapter 4. Design of flow management AIS message types and conversations

4.1. High-level design

In the high-level design of flow management messages no assumptions are made about the characteristics of the underlying transport layer. Focus here is to identify which pieces of information need to be exchanged, between whom, and when. Following this are detailed specifications mapping this outcome to specific protocols, such as AIS [AISSPEC5].

The messages to support flow management must have following characteristics:

- The message payload should be related to the current tactical execution, the imminent future. I.e. the message should not be designed for planning purposes or announcement of future intentions.
- The message should have carrying capability for as many waypoints as possible.
- The message should optionally support ETA or SOG per waypoint and vessel's TR.

4.1.1. Message types

Based on the Use cases it is noted, that the following messages are involved in flow management:

- **tactical voyageplan broadcast**. For a vessel to broadcast its tactical voyageplans.
- **tactical voyageplan inquiry**. An addressed message transmitted by coordination centers and vessels to inquire a vessel about its tactical voyageplan.
- **flow management suggestion**. An addressed message transmitted by coordination centers and vessels to suggest changes to a vessel's announced tactical voyageplan.

4.1.2. Payloads and transmission triggers

The sugested payloads and transmission triggers of these message types are the following.

Tactical voyageplan broadcast

Table 7. Information payload of message type **tactical voyageplan broadcast**.

Data field	Type	Description
Source ID	Required	Identity of sender, i.e. the vessel which owns the tactical route
Activation indicator	Required	Indication of whether the vessel cancels/deactives its voyageplan or whether it actively follows it.

Data field	Type	Description
Waypoints	Required	Positions of waypoints on the tactical voyageplan.
Active waypoint	Required	Indication of which of the waypoints the vessel is currently navigating towards.
TR	Optional	Ship’s turning circle radius in the current area (read more in Definitions).
ETA active waypoint	Required	Estimated time of arrival at active waypoint.
ETA last waypoint	Required	Estimated time of arrival at last waypoint.
ETA other waypoints	Optional	Estimated time of arrival at respective waypoint.

The message must only be transmitted by vessels.

The message is only transmitted if vessel is conned along an active voyageplan. In that case, the following transmission triggers apply:

1. Periodically. [Using AIS: To use periodic transmission intervals as defined for *dynamic information* in Table 1 of [AISSPEC5] (§4.2.1)]
2. On voyage plan activation.
3. On voyage plan change (change to waypoints or ETA at waypoints).
4. On voyage plan deactivation/cancellation.
5. On change of active waypoint.
6. As reply to message "tactical voyageplan inquiry".

Retransmission is not applicable.

Tactical voyageplan inquiry

Table 8. Information payload of message type **tactical voyageplan broadcast**.

Data field	Type	Description
Destination ID	Required	Receiver identification
Source ID	Required	Sender identification
Duration	Required	Relative time for which the vessel is requested to transmit tactical voyageplan periodically.

The message can be transmitted by vessels or shore-based coordination centres.

Retransmission is not applicable.

The following transmission triggers apply:

1. On need by control centre to receive tactical voyageplan from a vessel. In case of e.g.:
   - Vessel's arrival to controlled area.
   - Previously announced tactical voyageplan is invalid (e.g. expired, or vessel's manouvers deviate significantly from it).
   - Loss of data in control center.
2. On need by vessel to receive tactical voyageplan from another vessel.
   - The inquired vessel's intentions are unknown to the inquirying vessel; e.g. in case of
     - Tactical voyageplan was never transmitted by inquired vessel.
     - Tactical voyageplan was never received by inquirying vessel.
     - Information about another vessel's tactical voyageplan was lost onboard the inquirying vessel (e.g. due to system restart or improper operation).
   - The age of the most recently received tactical route from is higher than the nominal periodic update rate.

Flow management suggestion

Table 9. Information payload of message type **flow management suggestion***.*

Data field	Type	Description
Source ID	Required	Sender identification
Waypoints	Required	Positions of waypoints on the tactical voyageplan.
Suggested active waypoint	Required	Indication of which of the waypoints the vessel is currently navigating towards.
Suggested ETA of suggested active waypoint	Required	Suggested time of arrival at active waypoint.
Suggested ETA of suggested last waypoint	Required	Suggested time of arrival at last waypoint.
Suggested ETA of other suggested waypoints	Optional	Suggested time of arrival at respective waypoint.

The message must only be transmitted by shore-based coordination centres. It can only be addressed to vessels following an active tactical voyageplan announced via the tactical voyageplan broadcast message.

Retransmission is not applicable.

The following transmission triggers apply:

1. On need to suggest changes to tactical voyageplan to support flow management. E.g. if a coordination center determines, that better overall flow can be achieved by the receiving vessel:
   - changing ETA to announced waypoints.

4.2. Detailed message design

4.2.1. ASN.1

TBD

4.2.2. MSDL

TBD

4.2.3. AIS

Existing ASMs

A search in [ASMCOLL] reveals to candidate ASM's worth considering for the "tactical voyageplan" broadcast:

Title	Msg	DAC	FI	SU	Status	Registrant	Spec
Route information	8	1	27	5	in force	IMO Circ. 289	[ASM_001_27]
Intended route	8	219	1	3	initiation	Danish Maritime Authority	[ASM_219_01]

A search in [ASMCOLL] reveals to candidate ASM's worth considering for the "flow management suggestion":

Title	Msg	DAC	FI	SU	Status	Registrant	Spec
Route suggestion	6	219	2	5	initiation	Danish Maritime Authority	[ASM_219_02]

Review of ASM DAC=001; FI=27 - "Route information"

Review of the application specific message DAC=001; FI=27 defined by [ASM_001_27] in the context of flow management yields the following comments:

1. [ASM_001_27] specifies that "*13.1 This message … should only be used in when important route information … – not already provided by current official nautical charts or publications – needs to be relayed by authorities or vessels*".

   It is unclear whether a tactical voyageplan (in MONALISA terms) is "important route information". Certainly tactical voyageplans are not normally on any charts or publications; but are they "important" in the context of this message type?

2. [ASM_001_27] specifies that "*13.4 In order to allow advance notice, this message should be transmitted prior to the start date and time specified for the routing information. It should not be transmitted more than one day in advance*".

   The statement that the message should not "should not be transmitted more than one day in advance" indicates that this message is for planning purposes, and not related to the imminent tactical situation.

3. In the message layout [ASM_001_27] there is a field called "sender classification" which can only take one legal value: "1 = authority". Values 2-7 are reserved for future use. The value 0 is not defined in the specification, but since §13.1 indicates that the message can be used by vessels, perhaps 0 means that the sender is a vessel. But this is unclear.

4. The data field "duration" occupies 18 bits and thus supports a max. value of 262142 minutes (using 262143 to indicate value not available) [ASM_001_27]. 262142 minutes equals 4.369 hours or 182 days. This is far beyong the needs for a tactical voyageplan and is therefore not efficient bit-usage for this purpose.

5. In [ASM_001_27] the data field "number of waypoints" is redundant with message length and thus violates the design criteria Single point of truth. Since the specification states that "The number of waypoints is determined by the length of the message." the presence of this field is a mystery. 5 bits could be saved.

6. The message does not support individual ETA or turn radius per waypoint or SOG between waypoints.

In conclusion, DAC=001; FI=27 has an unclear specification, inefficient bit usage, and appears to be intended for planning purposes rather than the imminent tactical situation.

Therefore DAC=001; FI=27 is not suitable or recommmended for use in flow management.

Review of ASM DAC=219; FI=01 - "Intended route"

Review of the application specific message DAC=219; FI=01 defined by [ASM_219_01] in the context of flow management yields the following comments:

1. It is well-defined *when* this message must be sent.

2. First waypoint is always active waypoint - thus the message only carries future intentions.

3. The data field "ETA active WP" can be set one year ahead. The good thing about this, is that it complies with the Minimum no. of datatypes design criteria; but the bad thing is that it wastes bits; since the lifespan of a tactical voyageplan can probably be expressed in the order of hundres of minutes correponding to 10 bits of information.

4. In [ASM_219_01] the data field "number of waypoints" is redundant with message length and thus violates the design criteria Single point of truth. It is unclear whether message length or data field "number of waypoints" determines the no. of waypoint. In either case, the bits used for the data field "number of waypoints" could be saved.

5. The message does not support individual ETA or turn radius per waypoint or SOG between waypoints.

In conclusion, DAC=219; FI=01 has some of the same discrepancies as DAC=001; FI=27, but the events which trigger transmission are more well-defined, it is clear that this message is transmitted by vessels (not shore stations); and it is clear that this message intended for communicating immediate navigation intentions in the same way as required for tactical voyageplans.

Therefore it is recommended - to use DAC=219; FI=01 as a means for vessels to broadcast their tactical voyageplans flow management. - to suggest one new message, with the same purpose as DAC=219; FI=01, but with the extended capability of expressing individual ETA and turn radius per waypoint.

Review of ASM DAC=219; FI=02 - "Route suggestion"

Review of the application specific message DAC=219; FI=01 defined by [ASM_219_01] in the context of flow management yields the following comments:

1. The purpose of this message is to suggest a new route *geometry*.

2. The message does not support individual ETA or turn radius per waypoint or SOG between waypoints.

3. The data field "ETA active WP" can be set one year ahead. The good thing about this, is that it complies with the Minimum no. of datatypes design criteria; but the bad thing is that it wastes bits; since the lifespan of a tactical voyageplan can probably be expressed in the order of hundres of minutes correponding to 10 bits of information.

4. In [ASM_219_02] the data field "number of waypoints" is redundant with message length and thus violates the design criteria Single point of truth. It is unclear whether message length or data field "number of waypoints" determines the no. of waypoint. In either case, the bits used for the data field "number of waypoints" could be saved.

In conclusion, DAC=219; FI=02 has some of the same discrepancies as DAC=001; FI=27. It is clear that this message intended for communicating suggestions of route geometry - not speed-based flow management.

Therefore DAC=219; FI=02 is not suitable or recommmended for use in flow management.

4.2.4. Suggested AIS messages to support flow management

Following the arguments above, the following AIS messages are suggested to be used or defined for use in flow management:

Message purpose	Message type	Defined by
Tactical voyageplan broadcast	ASM DAC=219; FI=01	[ASM_219_01] Appendix: Tactical voyageplan broadcast (defined)
Tactical voyageplan broadcast, extended	ASM DAC=219; FI=02	Appendix: Tactical voyageplan broadcast, extended (proposal).
Tactical voyageplan inquiry	ASM DAC=001; FI=03	Appendix: Tactical voyageplan inquiry (proposal).
Flow management suggestion	ASM DAC=219; FI=04	Appendix: Flow management suggestion (proposal).

Chapter 5. Design of flow management MMS Message and Endpoint definition

Communication in MMS is specified through endpoint and broadcasts. In order to support the use cases, there is currently no particular need for broadcast, so this chapter outlines the endpoint definitions as well as the message formats.

Details of the service definitions is described in the Maritime Cloud Developer Guide, which is published online [MARCLOUDDEV].

5.1. MMS endpoints

5.1.1. Tactical Voyage Plan Exchange

One endpoint method is defined for an exchange of a tactical voyage plan.

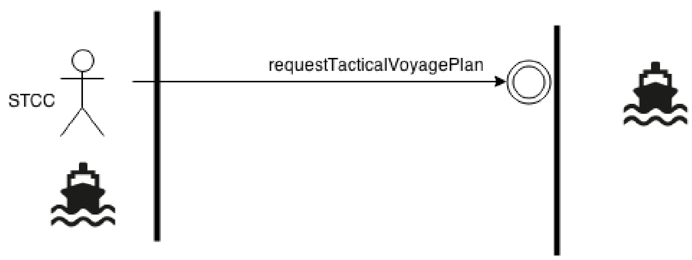

Figure 3. Requesting a Tactical Voyage Plan through defined endpoint.

STCC, a ship or another entity may request a tactical voyage plan from the endpoint. The request must specify the amount of minutes into the near future for the voyage plan.

The ship responds with the tactical voyage plan or rejects if it cannot comply.

Q?

- Should zero or negative timeWindow cause rejection or empty response or even default response?
- Is there a max time window to not call it tactical anymore?
- Can the ship just return a shorter timespan if it does not have/want to publish more?

In MSDL the endpoint definition should look like this:

Endpoint definition in MSDL

```
endpoint TacticalVoyagePlanEndpoint {

TacticalVoyagePlanResponse requestTacticalVoyagePlan(
//Specifies the amount of time in minutes to request
1: int timeWindow
);

}

message TacticalVoyagePlanResponse {

// The tactical voyage plan requested or null if no voyage plan
1: TacticalVoyagePlan plan;

// Explanation for rejections or comments on the tactical voyage plan
2: text textMessage;

};
```

The response include a tactical voyage plan and a message for any explanation.

Q?

- What’s the best way to signal errors or non-comply or limited-comply or other..?
- Should we include a response type (ACCEPT | REJECT | something…)
- Should we provide a unique identification of a tactical voyage plan (like a UUID, in case where we need to reference this specific tvp again)?

5.1.2. Flow Management Suggestion Exchange

Two endpoint methods are defined for flow management suggestions. One method for posting the suggestion and another endpoint method for the response.

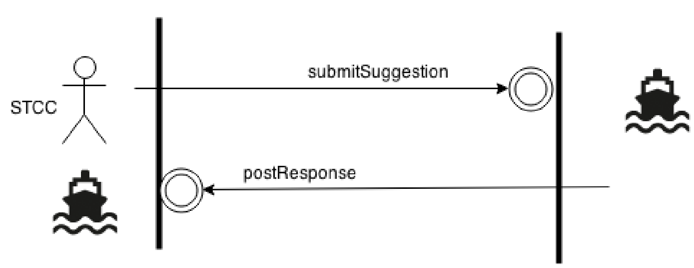

Figure 4. Suggesting a Tactical Voyage Plan through defined endpoint.

The asynchronous nature of the conversation allows the vessel to verify the suggestion before deciding upon further action.

Similar to the tactical voyage plan exchange the interaction can be ship to ship and ship to shore. The ship to ship scenario would enable Autonomous flow management.

The endpoints will be defined in MSDL like this:

Endpoint definition in MSDL

```
endpoint FlowManagementSuggestionEndpoint {
   void submitSuggestion(
     1: FlowManagementSuggestionRequest request
   );
}

endpoint FlowManagementResponseEndpoint {
   void postResponse(
     1: FlowManagementSuggestionResponse response
   );

}
```

The request and response are both of particular types containing relevant information about the request and response.

```
message FlowManagementSuggestionRequest {
/**
Conversation ID of the request.
A unique identifier which must be used in the response message.
*/
1: int64 requestId;

/** The tactical voyage plan to suggest. */
2: TacticalVoyagePlan suggestedVoyagePlan;

/** Text message included */
3: text textMessage;
}
```

When a suggestion is submitted it contains apart from the tactical voyage plan a transaction identifier for parties to identify this particular request at a later time. The same identifier will be used in responses but also in case of re-transmission.

The request also includes an optional message for the ship to understand the reason behind the suggestion.

```
enum FlowManagementSuggestionStatus {
  PENDING = 1;
  ACCEPTED = 2;
  REJECTED = 3;
}

message FlowManagementSuggestionResponse {
/**
Conversation ID of the request.
ID of the request to which we are responding.
*/
1: int64 requestId;

/** The answer status */
2: FlowManagementSuggestionStatus status;

/** Reply Text message */
3: text replyText;
}
```

The response include the original transaction identifier from the request. It also includes a status of the suggestion request, most particularly if the request has been accepted or rejected.

The return status of *PENDING* can be used as an intermediate response in cases where a decision has not been met yet. The ship can implement an automated response with *status=PENDING* at regular intervals.

5.1.3. Tactical Voyage Plan

The tactical voyage plan is a subset of the Dynamic Voyage Plan and contain route geometry and the near schedule.

It is based on the defined format in [ARCH] - Appendix A, however, some optional fields have been omitted for the tactical scenario.

A tactical voyage plan is returned by a ship when requested, but is also used for flow management suggestions. In the latter case the tactical voyage plan should be structural identical to the tactical voyage plan requested, but will differ only in the change content, such as waypoint position, speed, etd, eta, etc.

```
message TacticalVoyagePlan {
1: text routeName;

    // Waypoints
    2: list<Waypoint> waypoints;

    // Schedules
    3: list<Schedule> schedules;
};
```

Each tactical voyage plan have a route name which is mandatory in the Dynamic Voyage Plan. Otherwise the message contains the route geometry as a list of waypoints and a schedule.

The waypoints should be represented in order with the active waypoint as the first waypoint in the list.

The schedule information defines the current schedule between endpoints and is sorted by time.

Waypoint definition

Each waypoint contains the following definition

```
message Waypoint {

    /** The waypoint ID. */
    1: int waypointId;

    /** The position. */
    2: position waypointPosition;

    /** The turn radius of the vessel. In nautical miles. */
    // NBN: Not mandatory in spec, not used in AIS.
    3: double turnRadius;

    /** Do not need for the first waypoint, i.e. specify leg TOWARDS this waypoint, i.e.
INBOUND leg */
    // NBN: Not mandatory in spec, not used in AIS.
    4: Leg leg;

}
```

The waypoint ID refer to the waypoint ID from the Dynamic Voyage Plan. Each waypoint have a given position and a turn radius, when part of a direction change.

All but the first waypoint should have a leg definition of the inbound leg.

Leg definition

Each leg contains the following definition

```
message Leg {

    /** Cross track starboard distance in meters. */
    //NBN: Optional in spec, taken from ACCSEAS
    1: double xtdStarboard;

    /** Cross track port distance in meters. */
    //NBN: Optional in spec, taken from ACCSEAS
    2: double xtdPort;

    /** The geometry of the leg. Loxodrome=rhumb line(default), Orthodrome=great circle
*/
    //NBN: Optional in spec, taken from ACCSEAS
    3: GeometryType geometryType;

}

enum GeometryType {
    LOXODROME = 1;
    ORTHODROME = 2;
}
```

Each leg define the cross track distance in meters for starboard and port as well as the geometry type of the leg. Default geometry type is loxodrome.

Schedule definition

Each schedule contains the following definition

```
enum ScheduleType {
    MANUAL = 1;
    CALCULATED = 2;
}

message Schedule {
    /** The waypoint ID. */
    1: int waypointFrom;

    /** The waypoint ID. */
    2: int waypointTo;

    /** Calculated or Manual */
    3: ScheduleType scheduleType;

    /** The estimated time of departure (UTC) from the departing waypoint position. */
    4: timestamp etd;

    /** The estimated time of arrival (UTC) at the upcoming waypoint position. */
    5: timestamp eta;

    /** The speed over ground in knots. */
    //NBN: Optional in spec, taken from ACCSEAS
    6: double speed;
}
```

Each schedule element contains a reference to the departing waypoint and the arriving waypoint, matching the identifier in the waypoint list.

Schedules are defined in time order, which means that the calculated and the manual schedule elements of the Dynamic Voyage Plan is merged into one with a subsequent schedule type attached.

The schedule contains an ETD of the departing waypoint as well as an ETA of the arriving waypoint. When there is no significant stop-over at a waypoint the ETD may be omitted and merely substituted by the ETA of the previous schedule.

The schedule element also contains the speed over ground in knots as an easy indication of - but no substitution for - the arrival at the upcoming waypoint.

Chapter 6. Validation against design criteria

In this section the proposed messages are validated against the defined design criteria.

The validation is

- a textual description of how the design criteria was met
- quantitied as a score from 0 to 2, where 0 means no compliance with the criteria, 1 means partial compliance, and 2 means full compliance.

6.1. Validation of AIS messages against design criteria

6.1.1. General design criteria

No.	Criteria	Validation	Score
1	Design with the end-user in mind	Message flow is deducted from use cases. Actor involvement is analysed.	2
2	Design for multivendor environment	There are no vendor-specific issues in the proposed message formats. The proposed message formats are open and available for all vendors to implement.	2
3	Information transfer involving ships must be bandwidth efficient	The proposed messages can be long; and for AIS they involve up to 5 time slots. The potential to shorten messages is to eliminate data fields (which is hard) or to introduce compression (which breaks other design criteria).	1
4	Ship-shore interactions must be robust	No state is required in the messaging; any party can query a vessel's intentions. There is no guarantee of message arrival.	1
5	Ship-shore data IP connections must be initiated from ship	For AIS IP communication is not applicable.	0
6	Indication of trust	No trust is designed into AIS	0

The total theoretical score is 2 × 5 = 10; the obtained score is 6.
The design criteria compliance against general design criteria is 60%.

6.1.2. AIS-specific design criteria

No.	Criteria	Validation	Score
1	Consider updated definitions of ASM and related guidance, before developing new ASM	Relevant specifications and [ASMCOLL] was searched for candididate messages, which were evaluated.	2
2	Contribute to the IALA AIS ASM collection	After internal review the proposed AIS messages will be submitted to IALA for inclusion in [ASMCOLL]	2
3	Low transmission frequency	The minimal no. of events to trigger tranmission of messages have been identified and described per message.	2
4	Limit no. of VHF transmission slots	It is possible to send all proposed messages in 3 slots or fewer. But some messages support transmission of up to 5 slots.	1
5	Use 6-bit ASCII	There is no text in any of the proposed messages.	0
6	Fixed length messages	Some, but not all, of the proposed AIS messages have fixed-length. Variable-length messages is proposed to minimize the required no. of transmission slots.	1
7	Fixed bit-offset for fields	All the proposed messages have fixed bit-offsets for all fields.	2
8	Variable fields last	There are no variable-length fields in any of the proposed messages; unless the variable set of waypoints is seen as one variable-length field. And that fields is placed last.	2
9	One dispatch field	There are no dispatch-fields in any of the proposed AIS messages.	0
10	Minimum no. of datatypes	No new data types are introduced. Existing data types are reused.	2
11	Single point of truth	There are no redundant data fields in the proposed messages. For instance there is no field to indicate no. of following waypoints - that information is derived from message length.	2
12	Support stream-based parsers	Stream-based parsing is fully supported.	2
13	Don’t split data fields across datagrams	No data fields in the proposed AIS messages are split across multiple datagrams.	0
14	Check design using ASN.1	The propopsed AIS messages still remain to be expressed in ASN.1 notation	0
15	Provide a reference implementation	A full reference implementation for all proposed AIS messages is available.	2

No.	Criteria	Validation	Score
16	Provide test data sets for all message variants	Test data sets for all identied message variants are provided. They are listed in this paper and included in unit tests in the reference implementation.	2

The total theoretical score is 2 × (16-2) = 28; the obtained score is 22.
The design criteria compliance against AIS-specific design criteria is 79%.

6.2. Validation of MSDL messages against design criteria

6.2.1. General design criteria

No.	Criteria	Validation	Score
1	Design for multivendor environment	The Maritime Cloud is designed for multivendor environments.	2
2	Information transfer involving ships must be bandwidth efficient	The exchanged messages can be long. However, most fields of the tactical voyage plan that were already optional have been omitted from the MSDL. For an STCC this information is available from other sources.	1
3	Ship-shore interactions must be robust	Messaging in the Maritime Cloud is inherently robus.	2
4	Ship-shore data IP connections must be initiated from ship	Although MMS provide no direct dependency on IP it does mandate connections to be initated from the ship at any time.	2
5	Indication of trust	Trust are designed into the Maritime Cloud in the Maritime Identity Register as well as into the MMS caller context	2

The total theoretical score is 2 × 5 = 10; the obtained score is 9.
The design criteria compliance against general design criteria is 90%.

Chapter 7. Test data

The test data pairs listed in this section are calculated (and can be validated) as described in the appendix: Calculating test data pairs.

7.1. Tactical voyageplan broadcast

7.1.1. Variant 1: Cancel route

Parameter	Test value
Message ID	8
Repeat Indicator	0
Src ID	219000001
Spare	0
IAI	DAC = 219
	FI = 1
ETA active WP	UTC month = 0
	UTC day = 0
	UTC hour = 0
	UTC minute = 0
Duration	0
No. of waypoints	0

```
!AIVDM,1,1,0,,83@ndh@nh@0000000,3*4B
```

7.1.2. Variant 2: With 4 waypoints

Parameter	Test value
Message ID	8
Repeat Indicator	0
Src ID	219000001
Spare	0

Parameter	Test value
IAI	DAC = 219
	FI = 1
ETA active WP	UTC month = 1
	UTC day = 16
	UTC hour = 12
	UTC minute = 29
Duration	30
No. of waypoints	4
WP_0	lon = 10.025599
	lat = 55.846578
WP_1	lon = 10.049975
	lat = 55.828263
WP_2	lon = 10.071840
	lat = 55.811868
WP_3	lon = 10.125227
	lat = 55.796335

```
!AIVDM,1,1,0,,83@ndh@nhAPil01pP;NBwWwBVd5h2`CwSst2pJt1wgTA1Ldh0wnaDP,5*12
```

7.2. Tactical voyageplan broadcast, extended

7.2.1. Variant 1: Cancel tactical voyageplan

Parameter	Test value
Message ID	8
Repeat Indicator	0
Src ID	219000001
Spare	0
IAI	DAC = 219
	FI = 4

```
!AIVDM,1,1,0,,83@ndh@ni0,4*0D
```

7.2.2. Variant 2: With active waypoints, no following waypoints

Parameter	Test value
Message ID	8
Repeat Indicator	0
Src ID	219000001
Spare	0
IAI	DAC = 219
	FI = 4
WP_0, position	lon = 9.866598
	lat = 55.856310
WP_0, ETA	UTC hour = 23
	UTC minute = 59
WP_0, TCR	255

```
!AIVDM,1,1,0,,83@ndh@ni0FUCG?vhWEvwt,2*5A
```

7.2.3. Variant 3: With 12 following waypoints

Parameter	Test value
Message ID	8
Repeat Indicator	0
Src ID	219000001
Spare	0
IAI	DAC = 219
	FI = 4
WP_0	lon = 9.866598, lat = 55.856310, hour = 23, minute = 59, tcr = 255

Parameter	Test value
WP_1	lon = 9.887884, lat = 55.854913, eta = 24, tcr = 127
WP_2	lon = 9.980881, lat = 55.844410, eta = 1, tcr = 127
WP_3	lon = 10.012982, lat = 55.846337, eta = 7, tcr = 127
WP_4	lon = 10.028260, lat = 55.846337, eta = 11, tcr = 127
WP_5	lon = 10.035126, lat = 55.833710, eta = 15, tcr = 127
WP_6	lon = 10.054009, lat = 55.826865, eta = 16, tcr = 127
WP_7	lon = 10.060876, lat = 55.816836, eta = 6, tcr = 127
WP_8	lon = 10.076668, lat = 55.809216, eta = 4, tcr = 127
WP_9	lon = 10.125077, lat = 55.796384, eta = 17, tcr = 127
WP_{10}	lon = 10.262749, lat = 55.781906, eta = 255, tcr = 127
WP_{11}	lon = 10.269788, lat = 55.776307, eta = 16, tcr = 127
WP_{12}	lon = 10.272706, lat = 55.762402, eta = 1, tcr = 127

```
!AIVDM,3,1,0,,83@ndh@ni0FUCG?vhWEvwt5b6fSwcg`<?p;K1HWwAEH1OhFrge?vTs@>wPequ,0*7D
!AIVDM,3,2,0,,pOu9nPew1Kou@wqHQ1sv2p62awiho47t5hL;SwPUd3?p;R2HWvte`4OhG;:V?,0*27
!AIVDM,3,3,0,,ubHhRwPfvbROrjn?uw1N1M4wm;L23v2t6E1w`DQ0Gt,2*1B
```

7.3. Tactical voyageplan, inquiry

7.3.1. Variant 1: Inquiry with duration

Parameter	Test value
Message ID	6
Repeat Indicator	2
Src ID	219000001
Seq. no.	2
Dest. ID	219019416
Retransmit Flag	0
Spare	0
IAI	DAC = 219
	FI = 5

Parameter	Test value
Duration	240

```
!AIVDM,1,1,0,,63@ndh@l=v9P=dGh,0*08
```

7.4. Flow management suggestion

7.4.1. Variant 1: With active waypoints, no following waypoints

Parameter	Test value
Message ID	6
Repeat Indicator	0
Src ID	219000001
Seq no	0
Dest ID	219019416
Retransmit Flag	0
Spare	0
IAI	DAC = 219
	FI = 6
WP_0, position	lon = 9.866598
	lat = 55.856310
WP_0, ETA	UTC hour = 23
	UTC minute = 59

```
!AIVDM,1,1,0,,63@ndh@l=v9P=dH5aDmkwd9mOd,2*17
```

7.4.2. Variant 2: With 12 following waypoints

Parameter	Test value
Message ID	6
Repeat Indicator	0
Src ID	219000001

Parameter	Test value
Seq no	0
Dest ID	219019416
Retransmit Flag	0
Spare	0
IAI	DAC = 219
	FI = 6
WP_0, position	lon = 9.866598
	lat = 55.856310
WP_0, ETA	UTC hour = 23
	UTC minute = 59
WP_1	lon = 9.887884, lat = 55.854913, eta = 24
WP_2	lon = 9.980881, lat = 55.844410, eta = 1
WP_3	lon = 10.012982, lat = 55.846337, eta = 7
WP_4	lon = 10.028260, lat = 55.846337, eta = 11
WP_5	lon = 10.035126, lat = 55.833710, eta = 15
WP_6	lon = 10.054009, lat = 55.826865, eta = 16
WP_7	lon = 10.060876, lat = 55.816836, eta = 6
WP_8	lon = 10.076668, lat = 55.809216, eta = 4
WP_9	lon = 10.125077, lat = 55.796384, eta = 17
WP_{10}	lon = 10.262749, lat = 55.781906, eta = 255
WP_{11}	lon = 10.269788, lat = 55.776307, eta = 16
WP_{12}	lon = 10.272706, lat = 55.762402, eta = 1

```
!AIVDM,3,1,0,,63@ndh@l=v9P=dH5aDmkwd9mOd5b6fSwcg`<0ed5ROu5EP45fcsCwa>l3Pequ,0*52
!AIVDM,3,2,0,,pOu9nPd5gOm3wUR47Pf1PbOtL=i05hL;SwPUd30f89ROsjnP@5jjaSwJV<8Pf,0*46
!AIVDM,3,3,0,,vbROrjn?t5p5lCwDeh80g1U@Or58@4,2*0F
```

Chapter 8. Reference implementation

8.1. AIS

A reference implementation of encoding and decoding of the flow management related AIS messages programmed in Java is publically available in:

- https://github.com/tbsalling/AisLib/tree/flow-management.

8.1.1. Tactical voyageplan broadcast

The reference implementation of the *tactical voyageplan broadcast* message is located in

- https://github.com/tbsalling/AisLib/blob/flow-management/ais-lib-messages/src/main/java/dk/dma/ais/message/binary/BroadcastIntendedRoute.java

with an accompanying unit test class in

- https://github.com/tbsalling/AisLib/blob/flow-management/ais-lib-messages/src/test/java/dk/dma/ais/message/binary/BroadcastIntendedRouteTest.java

8.1.2. Tactical voyageplan broadcast, extended

The reference implementation of the *tactical voyageplan extended broadcast* message is located in

- https://github.com/tbsalling/AisLib/blob/flow-management/ais-lib-messages/src/main/java/dk/dma/ais/message/binary/TacticalVoyagePlan.java

with an accompanying unit test class in

- https://github.com/tbsalling/AisLib/blob/flow-management/ais-lib-messages/src/test/java/dk/dma/ais/message/binary/TacticalVoyagePlanTest.java

8.1.3. Tactical voyageplan, inquiry

The reference implementation of the *tactical voyageplan, inquiry* message is located in

- https://github.com/tbsalling/AisLib/blob/flow-management/ais-lib-messages/src/main/java/dk/dma/ais/message/binary/TacticalVoyagePlanInquiry.java

with an accompanying unit test class in

- https://github.com/tbsalling/AisLib/blob/flow-management/ais-lib-messages/src/test/java/dk/dma/ais/message/binary/TacticalVoyagePlanInquiryTest.java

8.1.4. Flow management suggestion

The reference implementation of the *flow management suggestion* message is located in

- https://github.com/tbsalling/AisLib/blob/flow-management/ais-lib-messages/src/main/java/dk/dma/ais/message/binary/FlowManagementSuggestion.java

with an accompanying unit test class in

- https://github.com/tbsalling/AisLib/blob/flow-management/ais-lib-messages/src/test/java/dk/dma/ais/message/binary/FlowManagementSuggestionTest.java

8.2. MMS

A reference of the MMS components is available in:

- https://github.com/dma-dk/MONALISA2.

8.2.1. MSDL specification

The reference implementation of the *flow management suggestion* and *tactical voyageplan exchange* is available in

- https://github.com/dma-dk/MONALISA2/tree/master/FlowManagement/Services

8.2.2. EPD Reference implementation

A reference implementation of the MMS components is available in

- https://github.com/dma-dk/MONALISA2/tree/master/FlowManagement/EPD

Which is a plugin component for the e-Navigation Prototype Displays (EPD) located here:

- https://github.com/dma-enav/EPD

- The Components should probably be moved to another repository, which is public
- The EPD Reference implementation is not finalized

Appendix A: AIS message definitions

The following AIS message definitions are proposed for flow management support.

Tactical voyageplan broadcast (defined)

Formally proposed specification copied from [ASM_219_01]:

This message allows the communication of a vessels intended route to other vessels and shore stations.

The rules for broadcasting this message are the following

a. Only broadcast when the vessel is following an activated route.
b. The route must be broadcast every six minutes, due to what is stated in ITU-R M.1371-4 (§4.2.1) regarding sending interval for voyage related information.
c. On route activation the route must be broadcast.
d. When active waypoint changes the route must be broadcast.
e. On route deactivation, or when a route is completed, an empty message with no waypoints must be sent to indicate that the vessel is not following an intended route.

The broadcast waypoints must start with the current active waypoint and include up to the 15 following waypoints, giving a maximum of 16 waypoints.

Broadcasting 16 waypoints will result in a 5-slot message. It is recommended to avoid messages with more than 3 slots, equivalent to no more than 8 waypoints.

See http://enav.frv.dk/ais_route_suggestion.pdf for usage and portrayal details.

Registrant: Danish Maritime Authority
Message number: 8
DAC: 219
FI: 1
Used by: DMA, EfficienSea
Number of Slots (max): 3
Reporting rate: Every 6 minutes and on active route change
How portrayed: See http://enav.frv.dk/ais_route_suggestion.pdf for usage and portrayal details.

Permitted as from: 11/03/2011
Status: initiation
Technical Point of contact:
Ole Borup
Danish Maritime Authority
obo@frv.dk

Details:
Table 2.1
Intended route (broadcast)

Parameter	No. of bits	Description
Message ID	6	Identifier for Message 8; always 8.
Repeat Indicator	2	Used by the repeater to indicate how many times a message has been repeated. 0 - 3 0 = default 3 = do not repeat anymore
Source ID	30	MMSI number of source station.
Spare	2	Not used. Set to zero. Note: [ASM_219_01] states 1 spare bit; but this is not compliant with the format of message type 8 in [AISSPEC5], which states 2 spare bits. 2 spare bits is assumed to be correct.
IAI	16	**DAC = 219; FI = 1**
ETA active WP		The ETA at the active waypoint (first waypoint). For a cancellation of active route, the default values can be used.
UTC Month	4	1 - 12 0 = not available = default
UTC Day	5	1 - 31 0 = not available = default
UTC Hour	5	0 - 23 0 = not available = default
UTC Minute	6	0 - 59 0 = not available = default
Duration	18	Minutes from ETA at active waypoint to ETA at the last broadcast waypoint. The duration allows for the calculation of an average intended speed on the broadcast route. + 0 = not available = default

Parameter	No. of bits	Description
Number of Waypoints	5	Number of Waypoints + 1 - 16 0 = no active route = cancel route 17 - 31 (not used)
Waypoints	n × 55	Variable number of waypoints 0 – 16 (55 bit each), refer to table 2.2.
Spare		Not used. Set to zero.
Total	**99-979**	**Occupies 2 – 5 slots.** 1 - 4 waypoints = 2 slots 5 - 8 waypoints = 3 slots 9 - 12 waypoints = 4 slots 13 – 16 waypoints = 5 slots

Table 2.2
Waypoints

Parameter	No. of bits	Description
WP Longitude	28	Longitude in 1/10,000 min, ±180 degrees as per 2's complement (East = positive, West = negative).
WP Latitude	27	Latitude in 1/10,000 min, ±90 degrees as per 2's complement (North = positive, South = negative).

Tactical voyageplan broadcast, extended (proposal)

Transmitter
Vessels only.

Transmission prerequisites
The message is only transmitted if vessel is conned along an active voyageplan.

Transmission triggering events
The following events must trigger a transmission of this message:

1. Periodically. [Using AIS: To use periodic transmission intervals as defined for *dynamic information* in Table 1 of [AISSPEC5] (§4.2.1)]
2. On voyage plan activation.
3. On voyage plan change
   (change to waypoints or change of ETA to any waypoint of more than 10 minutes).
4. On voyage plan deactivation/cancellation.
5. On change of active waypoint.
6. As reply to message "tactical voyageplan inquiry".

Retransmission
Retransmission is not applicable.

Message format Waypoints are denoted WP_0, WP_1, WP_i,..., WP_n and are navigated in sequence. WP_0 is the *active waypoint* currently steered towards. WP_i, where $i \geq 1$, is called *following waypoints*.

Parameter	No. of bits	Description
Message ID	6	Identifier for Message 8; always 8.
Repeat Indicator	2	Used by the repeater to indicate how many times a message has been repeated. 0 - 3 0 = default 3 = do not repeat anymore
Source ID	30	MMSI number of source station.
Spare	2	Not used. Set to zero.
IAI	16	**DAC = 219; FI = 4**

Parameter	No. of bits	Description
Message may end here to indicate cancellation of previously announced tactical voyageplan.		
WP$_0$, position	28	Longitude in 1/10,000 min, ±180 degrees as per 2’s complement (East = positive, West = negative).
	27	Latitude in 1/10,000 min, ±90 degrees as per 2’s complement (North = positive, South = negative).
WP$_0$, ETA	5	UTC hour Integer value Values outside the range 0-23 are illegal and must not be used. Values are current or future.
	6	UTC minute Integer value Values outside the range 0-59 are illegal and must not be used.
WP$_0$, TCR	8	Turn circle radius at the active waypoint. Type: Integer. Unit: 1/100 of a nautical mile. 0 = no value 1 - 255 = turn circle radius of 0.01 nm - 2.55 nm
Following waypoints with ETA and TCR	n × 63	Variable no. of planned waypoints and ETA’s. n {0..12} See table 2
Total	**56** **130** **201** **…** **982**	56 bits for cancellation. 130 bits for WP$_0$, no following WP’s. 201 bits for WP$_0$, 1 following WP. … 982 bits for WP$_0$, 12 following WP.

Table 10. Following waypoints.

Parameter	No. of bits	Description
WP_i, longitude	28	Longitude in 1/10,000 min, ±180 degrees as per 2's complement (East = positive, West = negative).
WP_i, latitude	27	Latitude in 1/10,000 min, ±90 degrees as per 2's complement (North = positive, South = negative).
WP_i, relative ETA	8	Relative ETA from previous waypoint; measured in minutes. Integer value; [0-255]. 0 = Not used. Illegal value. 1 - 255 = Relative ETA measured in number of minutes from previous waypoint.
WP_i, TCR	8	Turn circle radius at WP_i. Type: Integer. Unit: 1/100 of a nautical mile. 0 = no value 1 - 255 = turn circle radius of 0.01 nm - 2.55nm
Total	**71**	

Table 11. No. of transmission slots.

Payload	Bits	Slots
Cancellation	55	1
Active waypoint, no following waypoints	130	1
Active waypoint, 1 following waypoint	201	2
Active waypoint, 2 following waypoints	272	2
Active waypoint, 3 following waypoints	343	2
Active waypoint, 4 following waypoints	414	3
Active waypoint, 5 following waypoints	485	3
Active waypoint, 6 following waypoints	556	3
Transmitting more than 3 slots is not recommended		
Active waypoint, 7 following waypoints	627	4
Active waypoint, 8 following waypoints	*698*	*4*
Active waypoint, 9 following waypoints	*769*	*4*

Payload	Bits	Slots
Active waypoint, 10 following waypoints	*840*	*5*
Active waypoint, 11 following waypoints	*911*	*5*
Active waypoint, 12 following waypoints	*982*	*5*

Tactical voyageplan inquiry (proposal)

Transmitter
Vessels and coordination centres.

Transmission triggering events
The following events should trigger transmission:

1. On need by control centre to receive tactical voyageplan from a vessel. In case of e.g.:
   - A vessel's arrival to controlled area.
   - A vessel's previously announced tactical voyageplan is considered invalid by the inquirer, e.g. because
     - the timestamp of the active waypoint is in the past.
     - the vessel's manouvers deviate significantly from its announced tactical voyageplan.
   - Loss of data in control center.
2. On need by vessel to receive tactical voyageplan from another vessel.
   - The inquired vessel's intentions are unknown to the inquirying vessel; e.g. in case of
     - Tactical voyageplan was never transmitted by inquired vessel.
     - Tactical voyageplan was never received by inquirying vessel.
     - Information about another vessel's tactical voyageplan was lost onboard the inquirying vessel (e.g. due to system restart or improper operation).

Retransmission
Except in the sense of missing protocol acknowledgement as per [AISSPEC5], Annex 8 §3.5 — retransmission is not applicable.

Message format

Parameter	No. of bits	Description
Message ID	6	Identifier for Message 6; always 6. [Message type 25 could also be considered. But this message type is very rate and not known to be used in any other applications.]

Parameter	No. of bits	Description
Repeat Indicator	2	Used by the repeater to indicate how many times a message has been repeated. 0 - 3 0 = default 3 = do not repeat anymore
Source ID	30	MMSI number of source station.
Sequence number	2	0-3; refer to [AISSPEC5] §5.3.1, Annex 2
Destination ID	30	MMSI number of destination station.
Retransmit Flag	1	Retransmit Flag should be set upon retransmission: 0 = no retransmission = default 1 = retransmitted.
Spare	1	Not used. Set to zero.
IAI	16	**DAC = 219; FI = 5**
Duration	8	0 = One-shot inquiry with no request to transmit periodically *or* (if the addressed vessel is still periodically transmitting as a result of a previous inquiry from the same source) a request to cease periodic transmissions of tactical voyageplan. 1-255 = Duration (in minutes) for which the addressed vessel is requested to transmit its tactical voyageplan periodically, as per triggering criteria of Tactical voyageplan broadcast (defined) and Tactical voyageplan broadcast, extended (proposal). If a retransmission period (requested from the same source) has not yet expired, the duration is reset to the new value. Type: Integer.
Total	**96**	

Table 12. No. of transmission slots.

Payload	Bits	Slots
Inquiry	96	1

Flow management suggestion (proposal)

Transmitter
Coordination centers (for controlled flow management).

Transmission prerequisites
The message is only transmitted if the receiving vessel has previously broadcast a tactical voyage plan which is still considered valid by the control center (e.g. ETA of active waypoint is in the future).

This message can only be sent in response to a "Tactical voyageplan broadcast" or a "Tactical voyageplan broadcast, extended".

The latitude and longitude of suggested active and planned waypoints must match exactly those received in the latest "Tactical voyageplan broadcast" or a "Tactical voyageplan broadcast, extended". If this is not the case, the vessel, to which the flow management suggestion is addressed, must disregard it, and broadcast a new tactical voyageplan message.

Transmission triggering events
The following events must trigger a transmission of this message:

1. On coordination center determining that speed-based changes to tactical voyageplan of vessel will lead to a better overall flow.

Retransmission
Retransmission is not applicable.

Message format
Waypoints are denoted WP_0, WP_1, WP_i,..., WP_n and are navigated in sequence. WP_0 is the *suggested active waypoint* currently to be steered towards. WP_i, where $i \geq 1$, is called the *following suggested waypoints*.

Parameter	No. of bits	Description
Message ID	6	Identifier for Message 6; always 6.
Repeat Indicator	2	Used by the repeater to indicate how many times a message has been repeated. 0 - 3 0 = default 3 = do not repeat anymore
Source ID	30	MMSI number of source station.
Sequence number	2	0-3; refer to [AISSPEC5] §5.3.1, Annex 2

Parameter	No. of bits	Description
Destination ID	30	MMSI number of destination station.
Retransmit Flag	1	Retransmit Flag should be set upon retransmission: 0 = no retransmission = default 1 = retransmitted.
Spare	1	Not used. Set to zero.
IAI	16	**DAC = 219; FI = 6**
WP_0, position	28	Longitude in 1/10,000 min, ±180 degrees as per 2’s complement (East = positive, West = negative).
	27	Latitude in 1/10,000 min, ±90 degrees as per 2’s complement (North = positive, South = negative).
WP_0, ETA	5	UTC hour Integer value Values outside the range 0-23 are illegal and must not be used. Values are current or future.
	6	UTC minute Integer value Values outside the range 0-59 are illegal and must not be used.
Suggested following waypoints with relative ETA	n × 63	Variable no. of planned waypoints and ETA’s. n {0..12} See table "Suggested following waypoints." below.
Total	**154-1006**	

Table 13. Suggested following waypoints.

Parameter	No. of bits	Description
WP_i, longitude	28	Longitude in 1/10,000 min, ±180 degrees as per 2’s complement (East = positive, West = negative).

Parameter	No. of bits	Description
WP_i, latitude	27	Latitude in 1/10,000 min, ±90 degrees as per 2's complement (North = positive, South = negative).
WP_i, relative ETA	8	Relative ETA from previous waypoint; measured in minutes. Integer value; [0-255]. 0 = Not used. Illegal value. 1 - 255 = Relative ETA measured in number of minutes from previous waypoint.
Total	**63**	

Table 14. No. of transmission slots.

Payload	Bits	Slots
Suggested active waypoint, no following suggested waypoints	154	2
Suggested active waypoint, 1 following suggested waypoint	217	2
Suggested active waypoint, 2 following suggested waypoints	280	2
Suggested active waypoint, 3 following suggested waypoints	343	2
Suggested active waypoint, 4 following suggested waypoints	406	3
Suggested active waypoint, 5 following suggested waypoints	469	3
Suggested active waypoint, 6 following suggested waypoints	532	3
Transmitting more than 3 slots is not recommended		
Suggested active waypoint, 7 following suggested waypoints	595	4
Suggested active waypoint, 8 following suggested waypoints	*658*	*4*
Suggested active waypoint, 9 following suggested waypoints	*721*	*4*
Suggested active waypoint, 10 following suggested waypoints	*784*	*4*
Suggested active waypoint, 11 following suggested waypoints	*847*	*5*
Suggested active waypoint, 12 following suggested waypoints	*910*	*5*

Appendix B: Calculating test data pairs

A test data pair can be computed like this: First, a message variant is chosen - and test data values are chosen for each data field. This is an example for the *tactical voyageplan, inquiry* message:

Parameter	Bits	Test value (decimal)	Test value (binary)
Message ID	6	6	000110
Repeat Indicator	2	0	00
Src ID	30	219000001	001101000011011010110011000001
Seq. no.	2	0	00
Dest. ID	30	219019416	001101000011011111100010011000
Retransmit Flag	1	0	0
Spare	1	0	0
IAI	10	DAC=291	0011011011
	6	FI=5	000101
Duration	8	240	11110000
Total		**88**	

Then, concatenating all the binary values and grouping them into 6-bit nibbles yields:

```
000110 000011 010000 110110 101100 110000
010000 110100 001101 111110 001001 100000
001101 101100 010111 110000
```

Incidentally, the last nibble fills up to six bits. If it didn't zero's would have to be padded at the end until the total number of bits were a multiple of six.

Using table 2 in the "AIVDM/AIVDO Payload Armoring"-section of [RAYMOND], these 15 6-bit nibbles can be converted into ASCII like this:

```
000110 -> "6"
000011 -> "3"
010000 -> "@"
110110 -> "n"
101100 -> "d"
110000 -> "h"
010000 -> "@"
110100 -> "l"
001101 -> "="
111110 -> "v"
001001 -> "9"
100000 -> "P"
001101 -> "="
101100 -> "d"
010111 -> "G"
110000 -> "h"
```

In conclusion the ASCII-armoured representation of this message is: `63@ndh@l=v9P=dGh`.

In communication with a base station or a transponder, this ASCII-armoured value needs to be in the payload of an NMEA0183 message like VDM or VDO, like this:

`!AIVDM,1,1,0,,63@ndh@l=v9P=dGh,0*08`

A good explanation of NMEA encapsulation of AIS data is found in the "AIVDM/AIVDO Sentence Layer" section of [RAYMOND].

The *-separated suffix ("*08") is the NMEA 0183 data-integrity CRC32 checksum for the sentence, preceded by "*". It is computed on the entire sentence including the AIVDM tag but excluding the leading "!" and the trailing "*". The checksum is computed as the last to digits of the XOR of all of the bytes in the sentence in hexadecimal notation. As explained by [WIKINMEA] the C implementation can look like this:

```c
#include <stdio.h>
#include <string.h>

int checksum(char *s) {
  int c = 0;

  while(*s)
    c ^= *s++;

  return c;
}

int main()
{
  char mystring[] = "AIVDM,1,1,0,,63@ndh@l=v9P=dGh,0";
  printf("Checksum: 0x%02X\n", checksum(mystring));
  return 0;
}
```

Running the algorithm as a C program yields:

```
$ gcc checksum.c
$ ./a.out
Checksum: 0x08
```

Thus — this particular case — the checksum is 0x08 and thus the complete NMEA amour containing our AIS data is:

```
!AIVDM,1,1,0,,63@ndh@l=v9P=dGh,0*08
```

Glossary

Definitions

Term	Definition
Strategic voyageplan	MONALISA 2 term for long term planning that consists of a route with a voyage number (and other Route information), a list of waypoints (geometry), a schedule, charter parties, legal conditions, and more. When a Strategic voyage plan is given to the ship as a voyage order it changes to *dynamic voyageplan*.
Dynamic voyageplan	MONALISA 2 term for an optimised version of the *strategic voyageplan*
Tactical voyageplan	MONALISA 3 term for a dynamic voyageplan in conning mode; i.e. under tactical execution. Whole or parts of the tactical voyage plan can be transmitted to increase situational awareness and support flow management.
Turn circle radius	Merchant ships usually turn in a circle having a radius of about 6–8 times the length between perpendiculars. Turn radius varies little with speed, but can vary significantly between manouvers in deep and shallow waters. The radius depends on the size and geometry of a vessel, the size of its rudder, and the no. and characteristics of propellers. Cf. [SBTCD] for more.

Abbreviations

Abbreviation	Expansion	Description
MSDL	Maritime Service Definition Language	A computer language used to defined services in the maritime cloud
MMS	Maritime Messaging Service	Exchange of messages through the maritime cloud
AIS	Automatic Identification System	A tracking system used on ships and by vessel traffic services for identifying and locating vessels by electronically exchanging data with other nearby ships, base stations, and satellites.
ASM	Application Specific Message	Used only in the context of the automatic identification system, as a method of allowing "competent authorities" to define additional AIS message subtypes, based on message types 6, 8, 25, and 26 which support a custom payload.

Abbreviation	Expansion	Description
CC	Coordination Center	A term specific to this document invented to cover all types of VTS, STCC, and other centres with responsibility for traffic management and coordination.
STM	Sea Traffic Management	The aggregation of the seaborne and shore-based functions (sea traffic services, maritime space management and sea traffic flow management) required to ensure the safe and efficient manouvering of vessels during all phases of operation.
STCC	Sea Traffic Coordination Center	A central, shore-based, hub maintaining record of all vessels at sea using AIS and/or radar to enable managed distribution of vessel routes between ship-to-ship and ship-to-shore.
VTS	Vessel traffic service	A vessel traffic service is a marine traffic monitoring system established by public or port authorities, somewhat similar to air traffic control for aircraft.
IALA	International Association of Lighthouse Authorities	The International Asso ciation of Marine Aids to Navigation and Lighthouse Authorities is a non-profit organization founded collect and provide nautical expertise and advice.
ITU	International Telecommunication Union	The International Telecommunication Unio is an agency of the United Nations that is responsible for issues that concern information and communication technologies, such as coordinating the shared global use of the radio spectrum, promoting international cooperation in assigning satellite orbits, assisting in the development of worldwide technical standards.
ASCII	American Standard Code for Interformation Interchange	A character encoding scheme used in computers, communications equipment, and other devices that use text, to represent text with numbers.
ETA	Estimated time of arrival	-
ETD	Estimated time of departure	-

Abbreviation	Expansion	Description
OOW	Officer on watch	-
SOG	Speed over ground	Speed made good (often measured in knots).
TCR	Turn circle radius	Turning circle radius (often measured in nautical miles).

Bibliography

Standards and specifications

[AISSPEC5] "Recommendation ITU-R M.1371-5: Technical characteristics for an automatic identification system using time division multiple access in the VHF maritime mobile frequency band". February, 2014. International Telecommunications Union. Available from http://www.itu.int/rec/R-REC-M.1371-5-201402-I.

[IMOSN289] "Guidance on the use of AIS application-specific messages". Published as SN.1/Circ.289 by the International Maritime Organization (IMO). June 2, 2010.

[IALA144] "IALA Recommendation e-NAV - 144 On Harmonized implementation of Application Specific Messages (ASM)". Edition 1. June, 2011. International Association of Marine Aids to Navigation and Lighthouse Authorities.

[AISASM] "Application Specific Messages". IALA maintained collection of regional applications for AIS Application Specific Messages in use. http://www.e-navigation.nl/asm.

Articles and papers

[TOILS] "The Toils of AIS: A Case Study in Application Protocol Design And Analysis" by Eric S. Raymond and Kurt Schwehr. 2013. Available from http://gitorious.org/toils-of-ais/toils-of-ais/

[ARCH] "Architecture for STM in EMSN and STM Data format for Route Exchange".

[RAYMOND] "AIVDM/AIVDO protocol decoding" by Eric S. Raymond <esr@thyrsus.com>. Version 1.46, Aug 2014. http://catb.org/gpsd/AIVDM.html.

[WIKINMEA] "NMEA 0183", Aug 28, 2014. http://en.wikipedia.org/wiki/NMEA_0183.

Web resources

[ASN.1] "Abstract Syntax Notation One (ASN.1)". A standard and notation that describes rules and structures for representing, encoding, transmitting, and decoding data in telecommunications and computer networking. http://en.wikipedia.org/wiki/Abstract_Syntax_Notation_One.

[BDEC] "bdec". A set of tools for creating decoders and encoders for binary files given a high level specification. http://www.protocollogic.com/docs/tutorial.html.

[MONALISA2] "MONALISA 2.0". A joint project from 10 different countries in the European Union to introduce Sea Traffic Management (STM) and make real-time information available to all interested and authorised parties in the maritime world. http://monalisaproject.eu/.

[MARCLOUD] Maritime Cloud. A framework consisting of standards, infrastructure and governance that fascilitate secure interoperable information exchange between stakeholders in the maritime community using the principles of Service Oriented Architectures. http://www.maritimecloud.net/.

[MARCLOUDDEV] Marimtime Cloud Developer Guide. A guide for developers using the maritime cloud. Also includes a section on current MSDL. http://dev.maritimecloud.net/devguide/index.html#mms-and-services.

[ASMCOLL] "Application Specific Messages". A collection of application specific AIS messages approved by IALA-AISM. http://www.e-navigation.nl/asm.

[ASM_001_27] "Specification of Route information - (broadcast)". Specification of the AIS application specific message for route information broadcast. http://www.e-navigation.nl/content/route-information.

[ASM_219_01] "Specification of intended route - (broadcast)". Specification of the AIS application specific message for intended route broadcast. http://www.e-navigation.nl/content/intended-route.

[ASM_219_02] "Specification of route suggestion". Specification of the AIS application specific message for intended route broadcast. http://www.e-navigation.nl/content/route-suggestion.

[REFIMPL] "DMA AisLib - Java library for handling AIS messages". A full AIS message encoder and decoder library in Java — including a reference implementation of all messages proposed in AIS message definitions. https://github.com/tbsalling/AisLib/tree/flow-management.

[SBTCD] Blog entry on "Turning Circle Diameter for a Container Ship". http://shipsbusiness.com/turning-circle.html.