AIS TDMA Access schemes

Technical summary

1. SUMMARY

AIS Transceivers share the radio bandwidth allocated to AIS operation using Time Division Multiple Access (TDMA) techniques. AIS typically operates on two parallel VHF Marine Band radio frequency channels and each channel is shared in time between multiple users by dividing channel access into 2250 'slots' per minute.

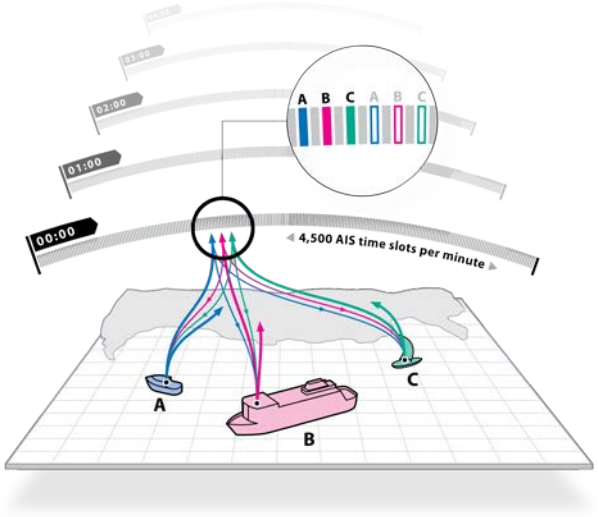

Figure 1 - AIS TDMA system

In a typical TDMA system (such as GSM) a controlling entity (a GSM Base Station) is used to allocate transmission slots to each user. As AIS must operate far offshore the system cannot rely on a controlling entity to allocate time slots to each user. This means that each AIS transceiver must determine its own TDMA slot allocation, and critically, it must avoid using a slot that is in use by another vessel within reception range in order to avoid transmissions clashing.

TDMA slot timing is derived from GPS time ensuring all AIS transceivers share a common accurate time reference.

The first TDMA access scheme developed for AIS was Self Organised Time Division Multiple Access (or SOTDMA) which is deployed in Class A AIS transceivers worldwide. A range of other access schemes which interoperate with SOTDMA are also available and are used for either specific types of data communication, or by specific categories of AIS device.

Selection of an appropriate TDMA access scheme that meets the requirements of an individual AIS device application, whilst maintaining the integrity of the AIS network for all users is critical to the success of any mass deployment.

2. SUMMARY OF AIS TDMA ACCESS SCHEMES

TDMA access schemes for use in AIS are defined by the top level AIS system specification in ITU-R M.1371-4[1]. The schemes defined are:

- SOTDMA - Self Organised Time Division Multiple Access
- RATDMA – Random Access Time Division Multiple Access
- ITDMA - Incremental Time Division Multiple Access
- FATDMA – Fixed Access Time Division Multiple Access
- CSTDMA – Carrier Sense Time Division Multiple Access
- Modified SOTDMA – Modifier Self Organised Time Division Multiple Access (also known as PATDMA, Pre-Announced Time Division Multiple Access)

The application of these schemes to existing AIS transceiver types is presented in Figure 2. Each access scheme has particular benefits, use cases and underlying hardware requirements; these are explored in the remainder of this document.

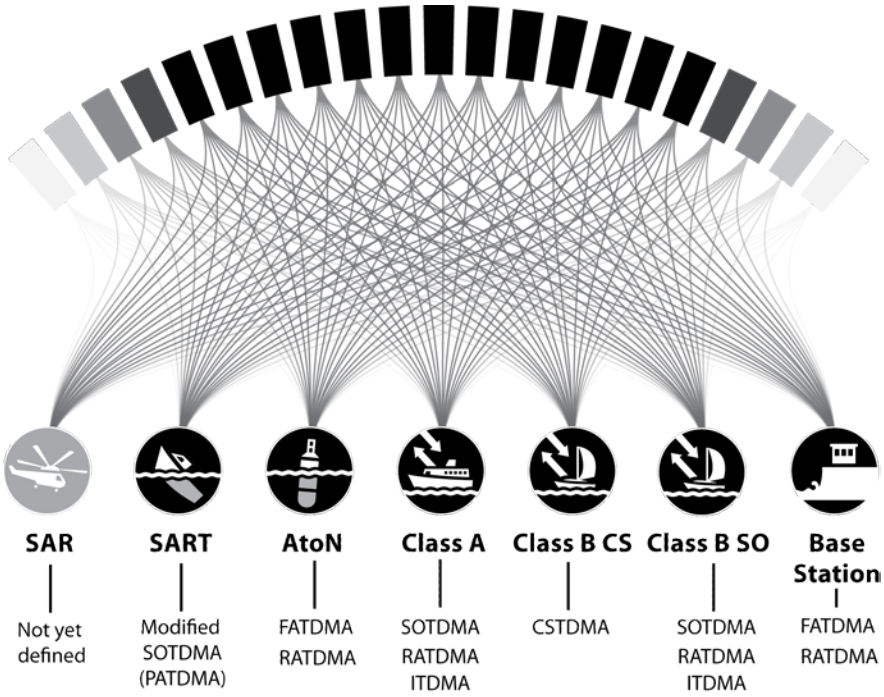

Figure 2 - TDMA usage by device type

3. DESCRIPTION OF TDMA ACCESS SCHEMES

A top level description of the operation of each TDMA access scheme defined for AIS is provided in the following sections.

3.1. SOTDMA - Self Organised Time Division Multiple Access

SOTDMA is the most complex TDMA access scheme defined for AIS and also provides the backbone for autonomous operation of the network offshore. The complete technical definition of SOTDMA can be found in ITU-R M.1371-4[1] Annex 2.

The key elements of SOTDMA operation are as follows:

- All stations share a common time reference (derived from GPS time) ensuring they can all accurately determine the start time of each TDMA slot.
- Each data transmission includes indication of the TDMA slot that will be used by the transmitting station for subsequent transmissions. This allows receiving stations to build up a 'map' of which slots are in use by which station.
- Each station avoids slots known to be in use by other stations for its own transmissions. This prevents two stations in range of one another using the same slot.
- As mobile stations move from one area to another they encounter new stations with different slot allocations. This may cause the station to modify its own slot allocation leading to a dynamic and self organising system over time and space.

SOTDMA also provides for dynamic and autonomous management of capacity in busy areas. Should a situation occur where all TDMA slots are occupied 'slot re-use' rules are applied. This allows the slots occupied by the stations most distant to a particular mobile station to be re-used for its own transmissions. This effectively reduces the size of an AIS 'cell' and ensures that position reports from the nearest vessels (which are most relevant to safety of navigation) are not affected.

The essential hardware requirements to support SOTDMA are:

- VHF transmitter capable of operating on any AIS channel in the marine VHF band
- Two VHF receivers capable of operating on any AIS channel in the marine VHF band
- Full time decoding of all received messages in order to populate an internal slot map
- GPS receiver to provide a time reference for TDMA timing
- Sufficient memory (RAM) to store a slot map for at least five minutes of TMDA slot allocations (the allocation status for 22500 TDMA slots)

3.2. RATDMA – Random Access Time Division Multiple Access

RATDMA is a simple TDMA access scheme available for certain types of data transmission and AIS device types. RATDMA is defined in ITU-R M.1371-4[1] Annex 2, §3.3.4.2.

RATDMA is used when a station needs to allocate a slot, which has not been pre-announced. This is generally done for the first transmission slot during data link network entry, or for messages of a non-repeatable character (such as transmission of text messages).

The key elements of RATDMA operation are as follows:

- All stations share a common time reference (derived from GPS time) ensuring they can all accurately determine the start time of each TDMA slot.
- The station transmitting using RATDMA uses its internal 'slot map' to randomly select a slot that is not currently in use by another station. It does not announce use of this slot, or subsequent slots used for non-periodic transmissions.
- RATDMA is not suitable for periodic transmissions as slots allocated using this technique can not be known by other AIS devices. Use of RATDMA for periodic transmissions by many devices would result in significant data collisions and compromise the integrity of the system.
- RATDMA is used by Class A AIS stations for 'network entry'. This occurs when a Class A device is first switched on and has not previously announced its own slot allocation using SOTDMA. An initial RATDMA transmission is used to solve this problem.

The essential hardware requirements to support RATDMA are:

- VHF transmitter capable of operating on any AIS channel in the marine VHF band
- Two VHF receivers capable of operating on any AIS channel in the marine VHF band
- Full time decoding of all received messages in order to populate an internal slot map
- GPS receiver to provide a time reference for TDMA timing
- Sufficient memory (RAM) to store a slot map for at least five minutes of TMDA slot allocations (the allocation status for 22500 TDMA slots)

3.3. ITDMA – Incremental Time Division Multiple Access

ITDMA is used in specific situations to pre-announce the transmission slots for non-periodic messages. ITDMA is defined in ITU-R M.1371-4[1] Annex 2, §3.3.4.1.

The key elements of ITDMA operation are as follows:

- All stations share a common time reference (derived from GPS time) ensuring they can all accurately determine the start time of each TDMA slot.
- The station transmitting using ITDMA uses its internal 'slot map' to randomly select a slot that is not currently in use by another station for its own future use. It uses ITDMA transmission to announce use of this slot.
- ITDMA is used when a station needs to announce a temporary change in the reporting interval of a periodic message, to pre-announce a non-periodic message (such as a safety related message) or during network entry.
- ITDMA is required to support SOTDMA operation; however it is not used as a standalone access scheme.

The essential hardware requirements to support ITDMA are:

- VHF transmitter capable of operating on any AIS channel in the marine VHF band
- Two VHF receivers capable of operating on any AIS channel in the marine VHF band
- Full time decoding of all received messages in order to populate an internal slot map
- GPS receiver to provide a time reference for TDMA timing
- Sufficient memory (RAM) to store a slot map for at least five minutes of TMDA slot allocations (the allocation status for 22500 TDMA slots)

3.4. FATDMA – Fixed Access Time Division Multiple Access

FATDMA is a manually managed TDMA access scheme where AIS devices are pre-configured to use specific TDMA slots for all transmissions. FATDMA is used only for AIS base stations and AIS AtoN stations. FATDMA is defined in ITU-R M.1371-4[1] Annex 2, §3.3.4.3.

The key elements of FATDMA operation are as follows:

- All stations share a common time reference (derived from GPS time) ensuring they can all accurately determine the start time of each TDMA slot.
- Stations are configured at installation to transmit in a specific TDMA slot or slots.
- Stations configured for FATDMA operation transmit a Data Link Management message which advises other stations of the FATDMA slot allocations. This blocks these slots from use by any other station in range. For this reason the use of FATDMA is minimised in order to minimise impact on the dynamic behaviour of the AIS network.
- Stations configured for FATDMA operation transmit only into the pre-defined slots.

The essential hardware requirements to support FATDMA are:

- VHF transmitter capable of operating on any AIS channel in the marine VHF band
- GPS receiver to provide a time reference for TDMA timing

Note that no receiver capability is required to support the FATDMA access scheme.

3.5. CSTDMA – Carrier Sense Time Division Multiple Access

CSTDMA is defined for Class B AIS stations and permits development of a low cost transceiver that is fully interoperable with SOTDMA transmissions whilst ensuring priority is always given to SOTDMA transmissions.

CSTDMA is defined in ITU-R M.1371-4[1] Annex 7.

The key elements of CSTDMA operation are as follows:

- TDMA slot timing is determined from the timing of AIS Class A or AIS base station transmissions within receiver range. GPS based timing is not required.

- Stations using CSTDMA continuously monitor the AIS radio channels background noise level. This background level is used as a reference for a received signal strength measurement at the start of each TDMA slot.

- When a transmission is required a TDMA slot is randomly selected and the signal strength at the start of the slot measured. If the signal strength is significantly above the background level the slot is assumed to be in use and the transmission is deferred. If the signal strength at the start of the slot is close to the background level the slot is assumed to be unused and the transmission is made.

- The 'listen before transmit' or 'carrier sense' scheme works on a slot by slot basis; this limits CSTDMA transmissions to a single TDMA slot. Multiple consecutive slots cannot be allocated using this technique.

The essential hardware requirements to support CSTDMA are:

- VHF transmitter capable of operating on any AIS channel in the marine VHF band

- Two VHF receivers capable of operating on any AIS channel in the marine VHF band

- Full time decoding of all received messages in order perform carrier sense measurements.

3.6. Modified SOTDMA – Modified Self Organised Time Division Multiple Access (or PATDMA)

Modified SOTDMA (or Pre-Announced TDMA) is a simple TDMA access scheme defined for use in transmit only devices. It has specific application in emergency beacons such as AIS Search and Rescue transceivers (SART).

Whilst sharing the 'SOTDMA' name with the SOTDMA access scheme described in section 3.1 this technique has little else in common with SOTDMA. Modified SOTDMA is defined in ITU-R M.1371-4 Annex 9 and described for use in "devices that have limited range and operate in a low volume". Further definition of the access scheme is given in the AIS SART equipment standard IEC61097-14[2].

The key elements of modified SOTDMA operation are as follows:

- All stations share a common time reference (derived from GPS time) ensuring they can all accurately determine the start time of each TDMA slot.
- A station randomly selects a slot for transmission. In the first transmission it announces its intention to use this slot for the following 8 minute period. At the start of the next period a new slot is randomly selected.
- Transmissions are made in 'bursts' of 8 messages once per minute. This is intended to ensure successful transmission when the device is operating near the surface of the sea and may be blocked from reception by periodic swell.
- The system is referred to as 'modified' SOTDMA as it uses the same pre-announcement system for future transmissions as the complete SOTDMA scheme described in section 3.1.
- As modified SOTDMA randomly selects transmission slots without knowledge of their use by other stations it is likely to create data collisions. This has been deemed acceptable for use in emergency beacons where the cost benefits of the modified SOTDMA system outweigh the impact of data collisions (which are small as emergency beacons do not operate regularly or in high densities).
- Due to the likelihood of random transmissions colliding with transmissions from other AIS transceivers the modified SOTDMA technique is not suited to use in systems installed in large volume, or where large numbers of systems are used in a small area.

The essential hardware requirements to support modified SOTDMA are:

- VHF transmitter capable of operating on any AIS channel in the marine VHF band
- GPS receiver to provide a time reference for TDMA timing

Note that no receiver capability is required to support the modified SOTDMA access scheme.

4. APPLICATION OF ACCESS SCHEMES TO AIS DEVICE TYPES

The applicability of each AIS TDMA access scheme to a particular AIS device type is presented in Figure 2. Whilst ITU-R M.1371-4[1] provides the top level definition of each access scheme the specific requirements for type of transceiver are defined in the relevant IEC equipment standard.

4.1. Class A AIS transceivers

The operation of Class A AIS transceivers is defined by the equipment and test standard IEC61993-2 Edition 1[3].

Class A transceivers use the following TDMA access schemes:

- SOTDMA is used for the majority of transmissions including all periodic transmissions (position reports).
- RATDMA and ITDMA are used during network entry (when the transceiver is first switched on) to enable initial transmissions and slot allocation
- RATDMA is used for non-periodic transmissions which can not be pre-announced. This would include transmission of text messages or safety related messages
- ITDMA is used to allocate slots for periodic transmissions when the reporting interval of a periodic message is changed (for example when the position reporting interval changes due a vessel speed change)

4.2. Class B 'CS' AIS transceivers

The operation of Class B 'CS' (Carrier Sense) transceivers is defined by the equipment and test standard IEC62287-1 Edition 2[4].

Class B 'CS' transceivers are permitted to use only the CSTDMA access scheme.

4.3. Class B 'SO' AIS transceivers

The operation of Class B 'SO' (Self Organising) AIS transceivers is defined by the equipment and test standard IEC62287-2[5]. This standard has recently been developed by the IEC technical working group and is currently in final draft format. Publication is anticipated during Q4 2012.

Class B ' SO' transceivers use the same access schemes as defined for Class A transceivers in section 4.1

4.4. AIS base stations

The operation of AIS base stations is defined by the equipment and test standard IEC62320-1 Edition 1[6].

AIS base stations use the FATDMA and RATDMA access schemes. FATDMA slot allocations are manually configured and broadcast to other AIS transceivers using data link management messages. RATDMA transmissions are typically used for non-periodic messages such as broadcast of safety related messages.

4.5. AIS Aids to Navigation transceivers

The operation of AIS Aids to Navigation is defined the equipment and test standard IEC62320-2 Edition 1[7].

AIS Aids to Navigation use either the FATDMA or RATDMA access scheme depending on their hardware configuration.

- A Type 1 AIS AtoN with transmit only capability uses the FATDMA access scheme. This requires a nearby base station to reserve the slots used by the AIS AtoN via data link management messages.

- A Type 3 AIS AtoN with both receive and transmit capability can use either the FATDMA access scheme (with base station reservations) or the RATDMA access scheme. The latter allows the AIS AtoN to autonomously allocate slots for its own transmissions as required.

4.6. AIS Search and Rescue transceivers (SART)

The operation of AIS Search and Rescue transceivers is defined in the equipment and test standard IEC61097-14 Edition 1[2].

AIS SARTs use only the modified-SOTDMA access scheme specifically defined for burst transmission in low volume emergency beacon applications.

5. REFERENCES

[1] **International Telecommunication Union**
Recommendation ITU-R M.1371-4 (04/2010) - Technical characteristics for an automatic identification system using time-division multiple access in the VHF maritime mobile band.

[2] **International Electrotechnical Commission**
International standard IEC61097-14 Edition 1 (02/2010) - Global maritime distress and safety system (GMDSS) – Part 14: AIS search and rescue transmitter (AIS-SART) – Operational and performance requirements, methods of testing and required test results

[3] **International Electrotechnical Commission**
International standard IEC61993-2 Edition 1 (12/2001) - Maritime navigation and radiocommunication equipment and systems – Automatic identification systems (AIS) Part 2: Class A shipborne equipment of the universal automatic identification system (AIS) – Operational and performance requirements, methods of test and required test results.

[4] **International Electrotechnical Commission**
International standard IEC62287-1 Edition 2 (11/2010) - Maritime navigation and radiocommunication equipment and systems – Class B shipborne equipment of the automatic identification system (AIS) – Part 1: Carrier-sense time division multiple access (CSTDMA) techniques

[5] **International Electrotechnical Commission**
International standard IEC62287-2, CDV Draft - Maritime navigation and radiocommunication equipment and systems – Class B shipborne equipment of the automatic identification system (AIS) – Part 2: Self-organising time division multiple access (SOTDMA) techniques

[6] **International Electrotechnical Commission**
International standard IEC62320-1, Edition 1 (2007) - Maritime navigation and radiocommunication equipment and systems — Automatic Identification Systems (AIS) — Part 1: AIS Base Stations — Minimum operational and performance requirements, methods of testing and required test results

[7] **International Electrotechnical Commission**
International standard IEC62320-2 Edition 1 (03/2008) - Maritime navigation and radiocommunication equipment and systems – Automatic identification system (AIS) – Part 2: AIS AtoN Stations – Operational and performance requirements, methods of testing and required test results