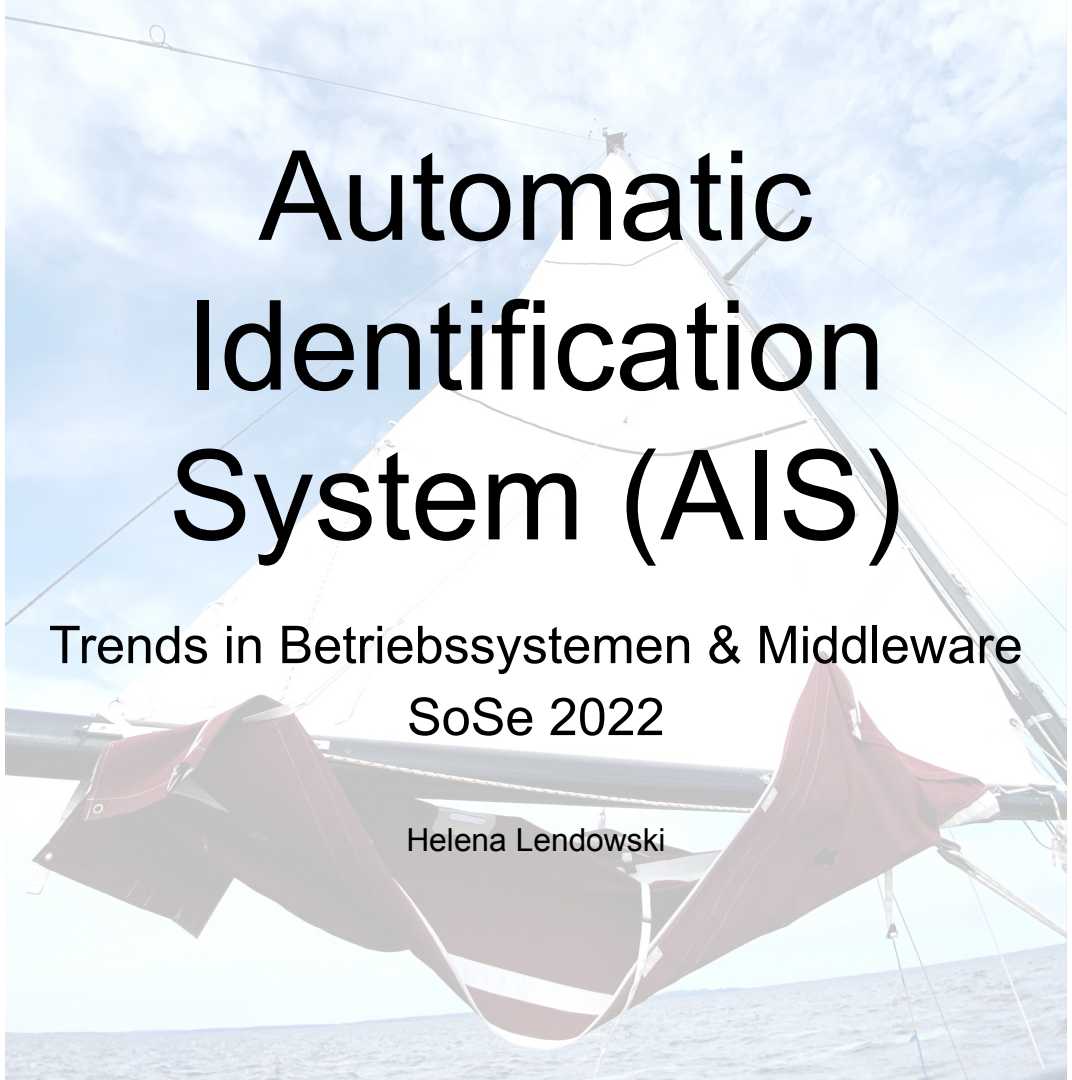


Automatic Identification System (AIS)

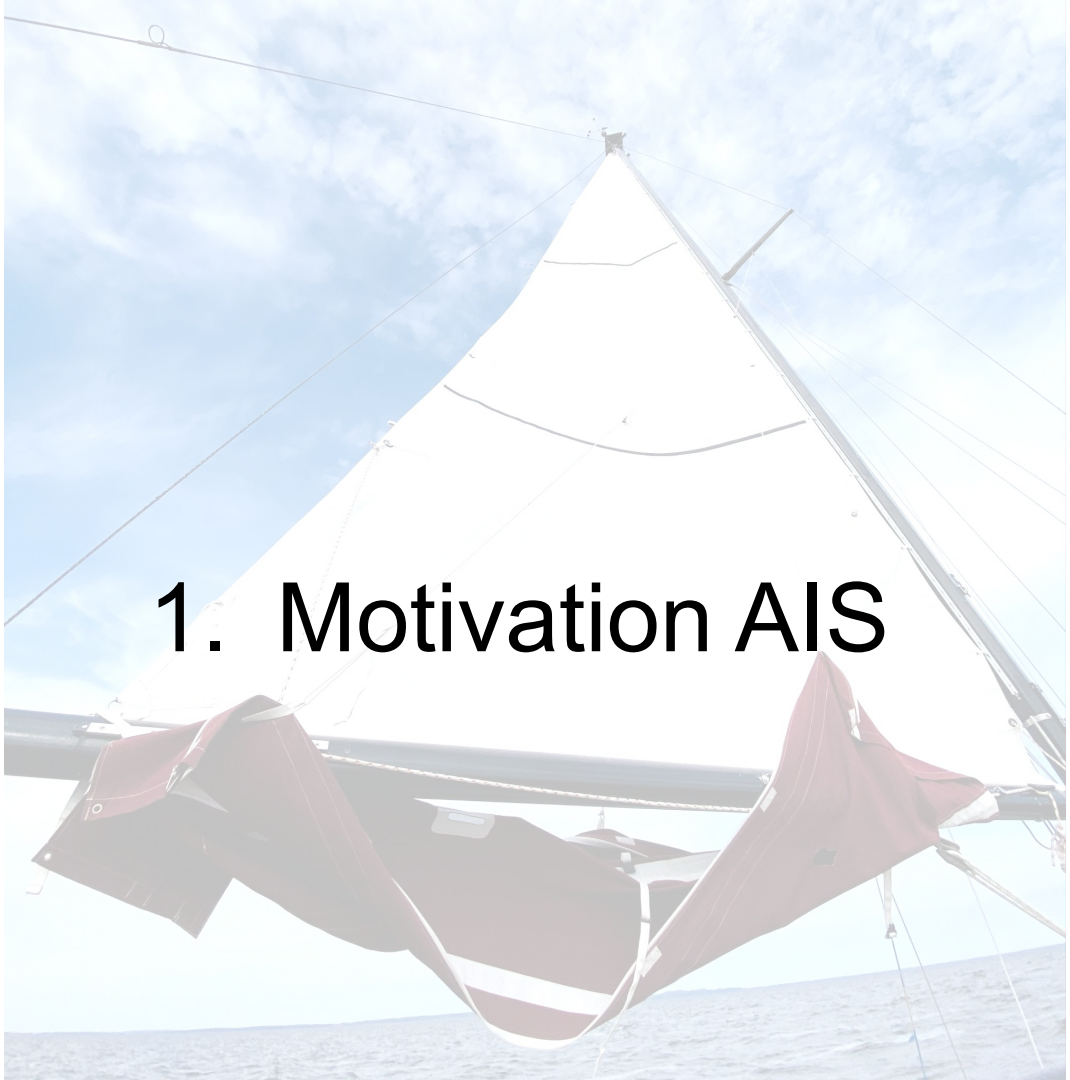
Trends in Betriebssystemen & Middleware

SoSe 2022

Helena Lendowski

Agenda

1. Motivation AIS
2. Functionality of AIS
3. AIS tooling
4. Collision detection: demo, implementation & relevant data
5. Future work



1. Motivation AIS

Why AIS?

ensure safety at sea

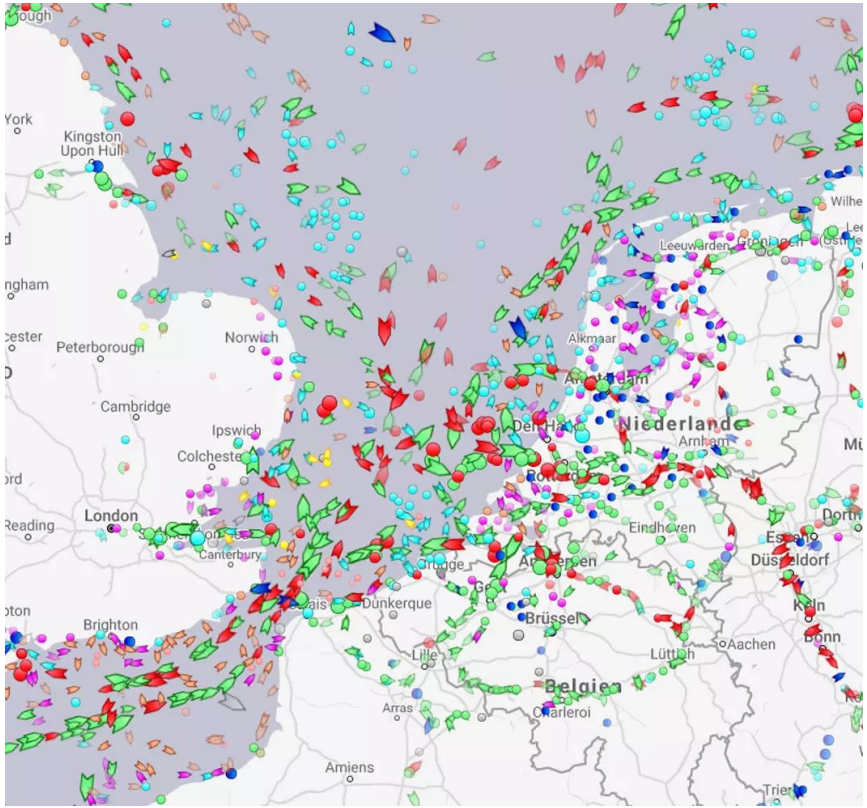
vessel identification system

collision avoidance

sea traffic control: monitoring of vessels

visibility in real time (MarineTraffic & Vesseltracker)

search & rescue (SAR)



AIS vs. radar

- view behind solid objects

Research

… with AIS-data

- cargo weight, estimated based on draft and vessel size (Jia, Prakash, & Smith, 2018)
- global oil trade forecast using AIS data by aggregating the volume of ships at sea (Adland, Jia, & Strandenes, 2017)
- port performance (Chen et al., 2016)
- environmental impacts of shipping (Gerritsen, Minto, & Lordan, 2013) assessed at the ship level

AIS types

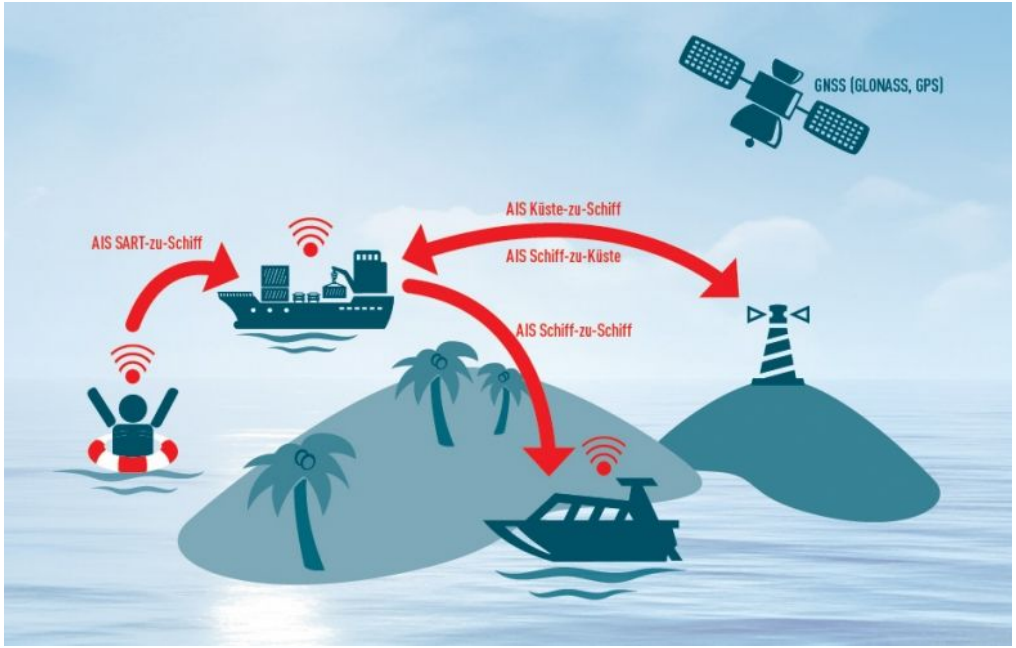
vessel-based AIS transceivers

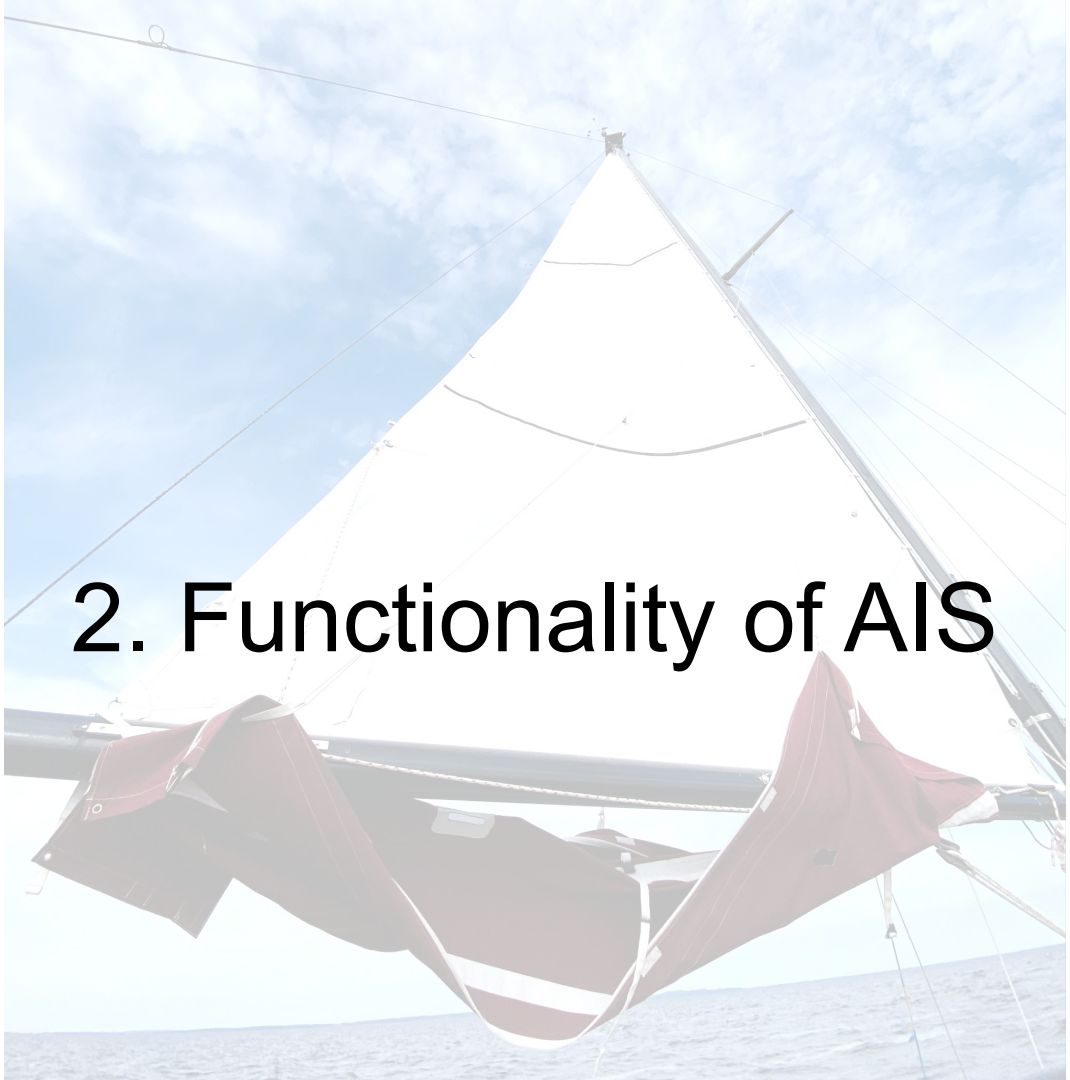
terrestrial-based AIS (T-AIS)

satellite-based AIS (S-AIS)

aids to navigation (AtoN)

search and rescue transmitter (SART) / man overboard (MOB)





2. Functionality of AIS

How does AIS work?

very high frequency (*VHF*) transmitter & VHF receiver

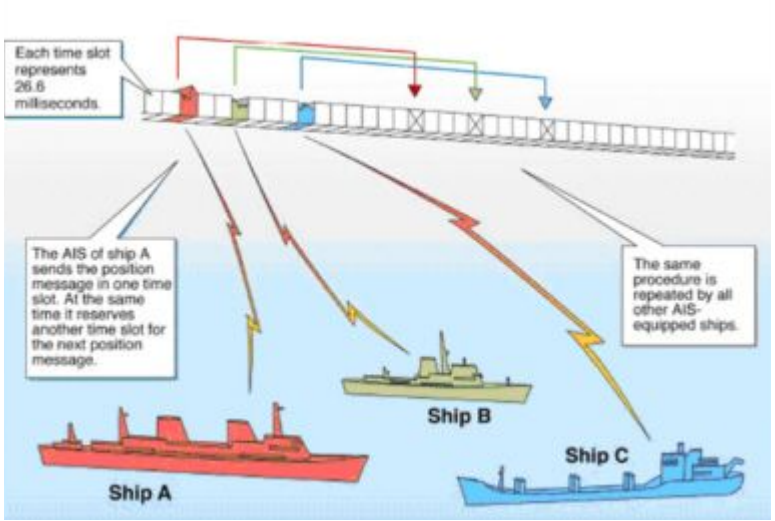
GPS

alternating on 2 channels: VHF channel 87B & 88B

- AIS channel A: 161.975 MHz
- AIS channel B: 162.025 MHz

data protocol: High-Level Data Link Control (HDLC)

AIVDM/AIVDO sentences



access of vessel-based AIS transceivers

- class A Self Organising Time Division Multiple Access (SOTDMA)
- class B Carrier Sense Time Division Multiple Access (CSTDMA)

AIS-data

Type of Information	Information	Broadcasting Rate
Dynamic Information	Maritime Mobile Service Identity number (MMSI) Ship position Speed over ground Course over ground Navigational status Time Etc.	At anchor or moored (<3 kts): 3 min At anchor or moored (>3 kts): 10 s Ship 0–14 kts: 10 s Ship 0–14 kts and changing course: 3.3 s Ship 14–23 kts: 6 s Ship 14–23 kts and changing course: 2 s Ship >23 kts: 2 s
Static and Voyage-related Information	MMSI number Ship type Length and beam Estimated time of arrival Destination Etc.	Every 6 min and on request

Range

The higher the antenna and the higher the transmitting power, the greater the range.

AIS has much longer vertical than horizontal transmission. 1 Nm = 1.852 km

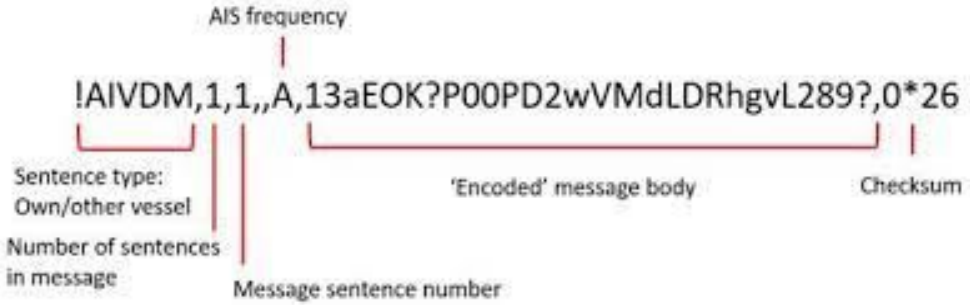
Transponders	W	Range in Nm
Class A	12.5	20-25
Class B+	5	10-12
Class B	2	7-8
MOB/SARTs	1	3-4
T-AIS		up to 54 (50–100 km)
S-AIS		up to 215,983 (400 km)

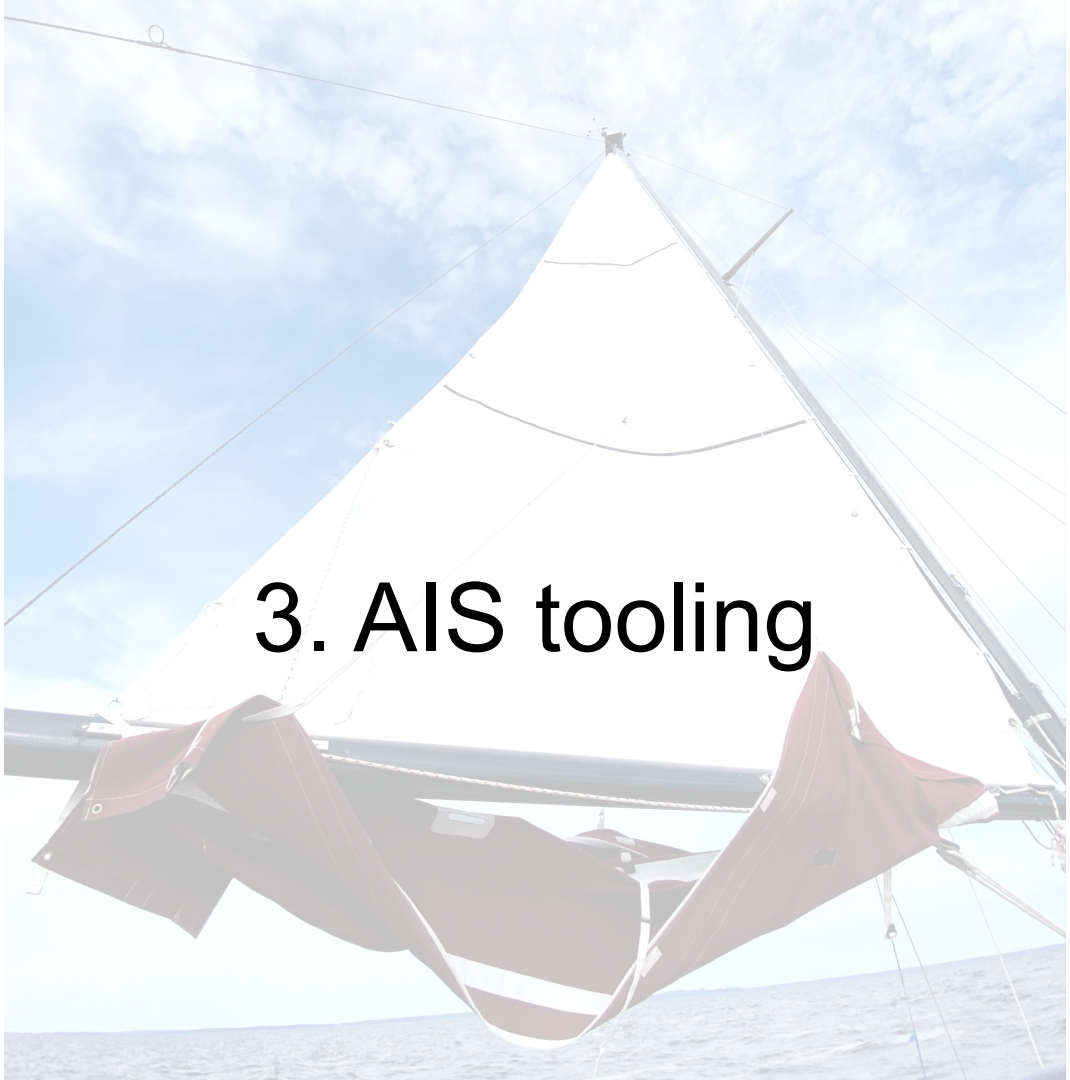
AIVDM/AIVDO sentences

6-bit binary coding

using the NMEA 0183 or NMEA 2000 data formats

sample message:





3. AIS tooling

Hardware

software-defined radio (SDR): de-/modulation of radio signals

VHF range: 30 MHz to 300 MHz

VHF antenna

RTL-SDR

GPS

Universal Software Radio Peripheral (USRP)

SDR

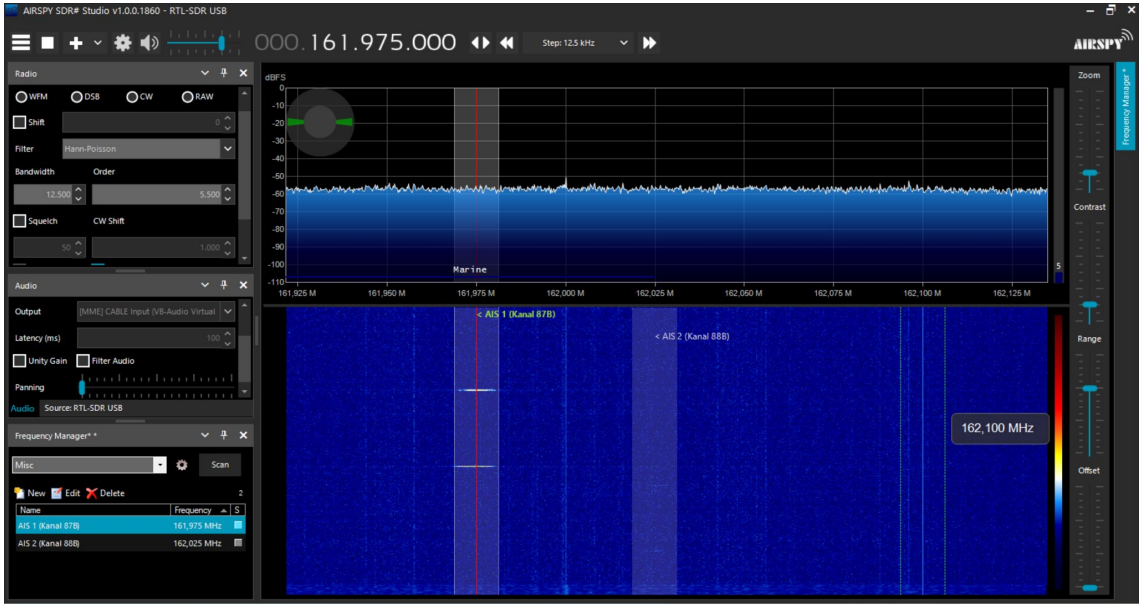
SDR package

AIRSPY: https://airspy.com/download/

- **SDRSharp**
- Airspy drivers
- HackRF driver
- **USRP driver**
- **RTL-SDR driver**

USRP Hardware Driver (UHD)

Zadig driver for RTL-SDR on Windows



Problems

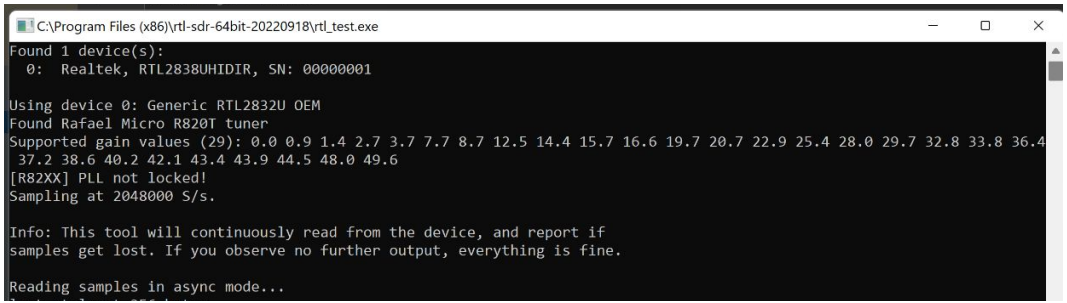
issues with libraries *librtlsdr*, *libusb1.0* and installing the appropriate *udev rules* (Windows & Linux)

solution with OsmoSDR and UHD and USRP Manual “Binary Builds” instructions on https://osmocom.org/projects/rtl-sdr/wiki/Rtl-sdr and https://files.ettus.com/manual/page_build_guide.html (*last accessed*: 14.08.2022)

getting started with SDR: often no proper explanation of the value settings (e.g., filter, sample rate, gain, …)

gain (= frequency correction (ppm)) and **sample rate** depend on device!

center frequency:
162 MHz (161.975 MHz / 162.025 MHz)



RTL-SDR values:

- gain: 1.4 ppm
- sample rate: 2.048 MHz

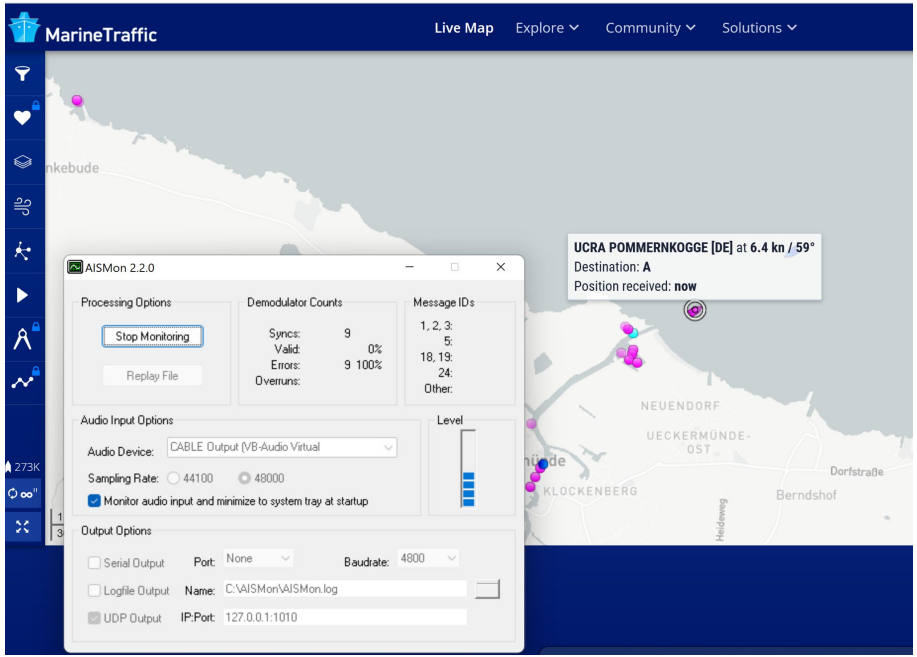
Software for signal processing to NMEA

AISMon: demodulator/decoder which outputs AIS-data in NMEA format

SDR: narrow-band frequency modulation (NFM)

send signal via virtual audio cable to AISMon

100% errors while being in the marina



Software for signal processing to NMEA

GNURadio: provides signal processing blocks to implement software radios

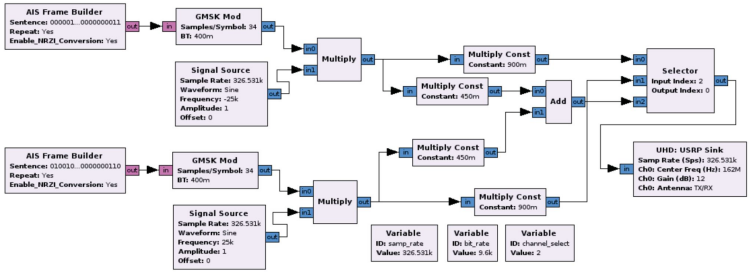


Figure 3: *AISTX* architecture on GnuRadio.

AIS Frame Builder block / AIS transmitter (AISTX) (available on https://github.com/trendmicro/ais) for GNURadio is not compatible with GNURadio v 3.9+

- Balduzzi, M., Pasta, A., & Wilhoit, K. (2014, December). A security evaluation of AIS automated identification system. In *Proceedings of the 30th annual computer security applications conference* (pp. 436-445).
- Cruz, F. R. G., Gania, R. C. M., Garcia, B. W. C., & Nob, J. C. R. (2018). Implementing Automatic Identification System Transmitter on Software Defined Radio.

BitsToAIS-NMEA block

- Fun With Electronics (2012). Automatic Identification System (AIS) using GNU Radio. Available on https://www.funwithelectronics.com/?id=9 (last accessed 10.09.2022)

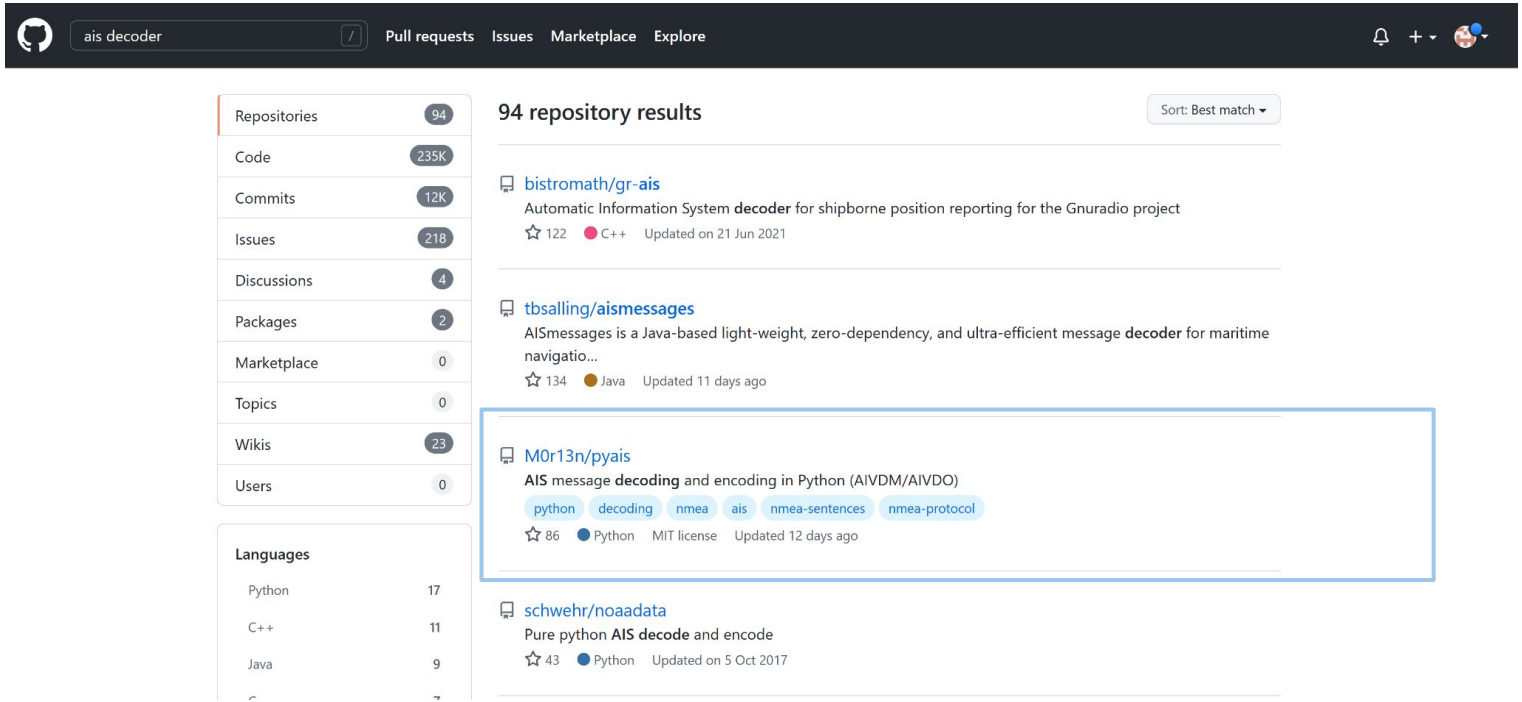
Software SDRangel

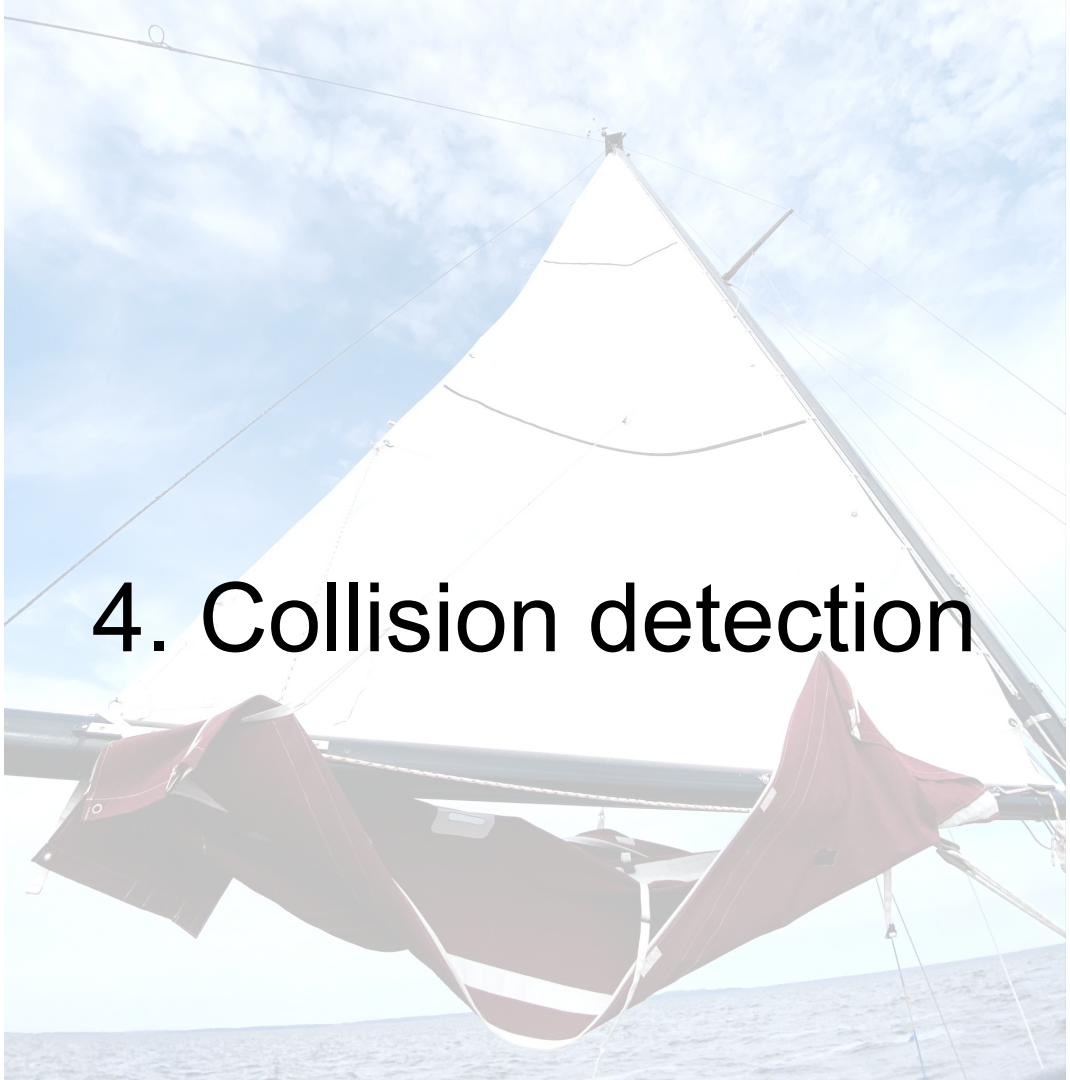
Video

Software AIVDM/AIVDO decoder

AIS decoder expects NMEA format

many projects





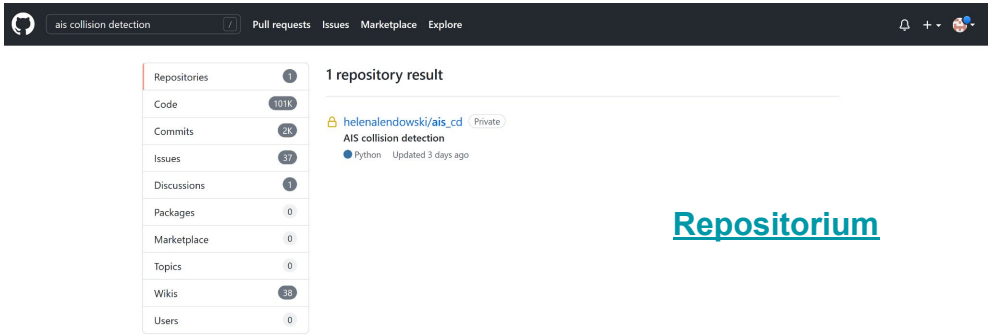
4. Collision detection

AIS collision detection related work on GitHub

AIS catcher (C++):
https://github.com/jvde-github/AIS-catcher

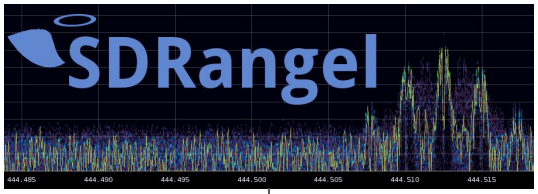
collision risk assessment for vessels (Python):
https://github.com/ByronAH/Collision-Risk-Assessment-for-Vessels

safety device for fishing vessels based on AIS (Python):
https://github.com/vjg28/Device-for-ship-detection



Repositorium

AIS collision detection implementation



UDP
data format: NMEA

Collision detection demo

Video

AIS message types

01 Position Report Class A 	15 Interrogation
02 Position Report Class A (Assigned schedule)	16 Assignment Mode Command
03 Position Report Class A (Response to interrogation) 	17 DGNSS Binary Broadcast Message
04 Base Station Report 	18 Standard Class B CS Position Report 
05 Static and Voyage Related Data 	19 Extended Class B Equipment Position Report
06 Binary Addressed Message	20 Data Link Management
07 Binary Acknowledge	21 Aid-to-Navigation Report
08 Binary Broadcast Message	22 Channel Management
09 Standard SAR Aircraft Position Report	23 Group Assignment Command
10 UTC and Date Inquiry	24 Static Data Report 
11 UTC and Date Response	25 Single Slot Binary Message
12 Addressed Safety Related Message	26 Multiple Slot Binary Message With Communications State
13 Safety Related Acknowledgement	27 Position Report For Long-Range Applications
14 Safety Related Broadcast Message	

GPS

$GNRMC: Time, date, position, course, speed data (kn)

position format serial GPS:

latitude in ‘DDMM.MMMMM’ format **lat_dir** ‘N’ or ‘S’

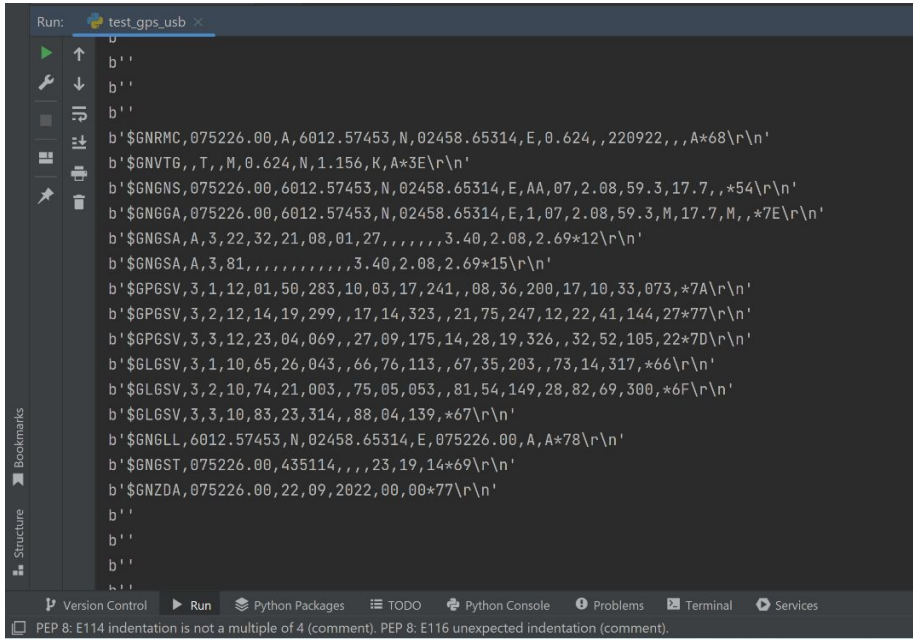
longitude in ‘DDDMM.MMMMM’ format **lon_dir** ‘E’ or ‘W’

different position formats:

sexagesimal degree: 40° 26′ 46″ N 79° 58′ 56″ W

degrees and decimal minutes: 40° 26.767′ N 79° 58.933′ W

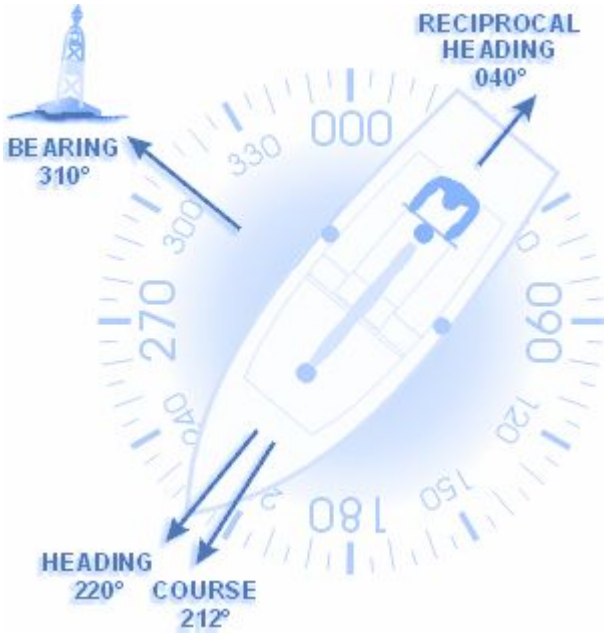
decimal degrees: +40.446 -79.982 ← AIS data format



Nautical terminology

true north: fixed point on a map and it will never change (North Pole)

magnetic north: north of a compass needle based on the earth's magnetic field; shifts over time thanks to magnetic variation



course: intended/planned direction to reach a destination

heading: direction the vessel is pointed at a given moment

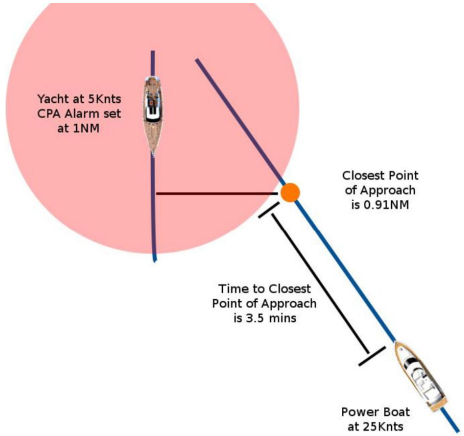
bearing: angle between north and the direction of another object/ your destination

relative bearing: angle between the heading of the vessel and the object/ destination (heading and course are aligned → relative bearing = 0°)

CPA & TCPA of a target

closest point of approach (cpa): computing the minimal distance between two ships

time to closest point of approach (tcpa)



AIS received data relative to true north

haversine formula: for the great-circle distance

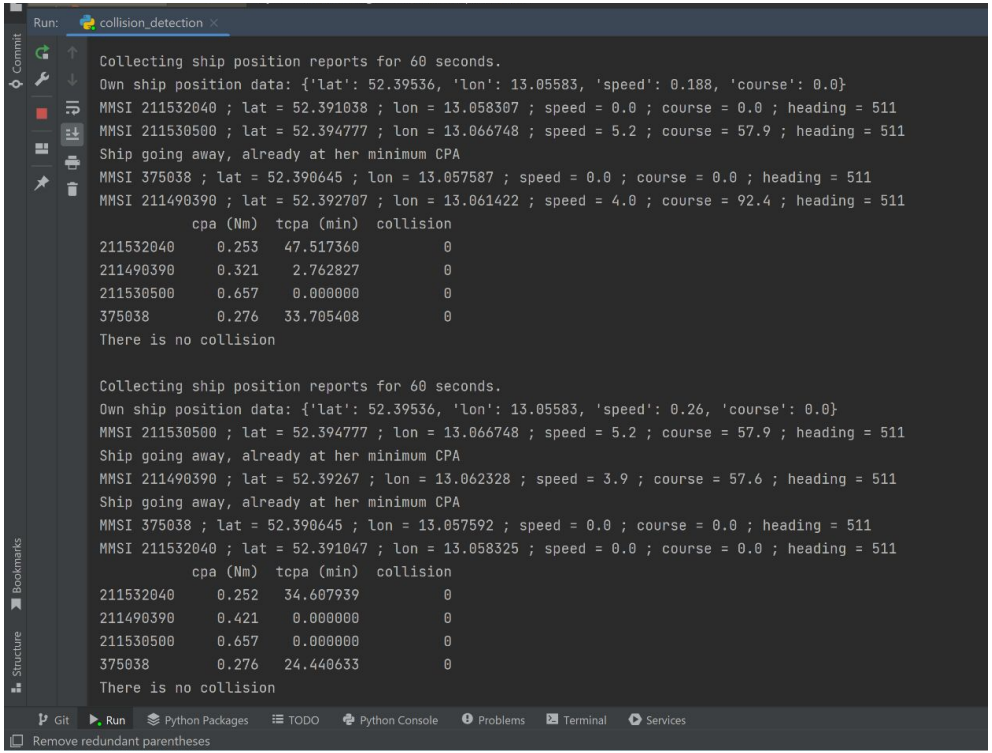
automatic radar plotting aids (ARPA)

ARPAoCALC library: https://github.com/nawre/arpaocalc

AIS data insight

dynamic data: heading = 511

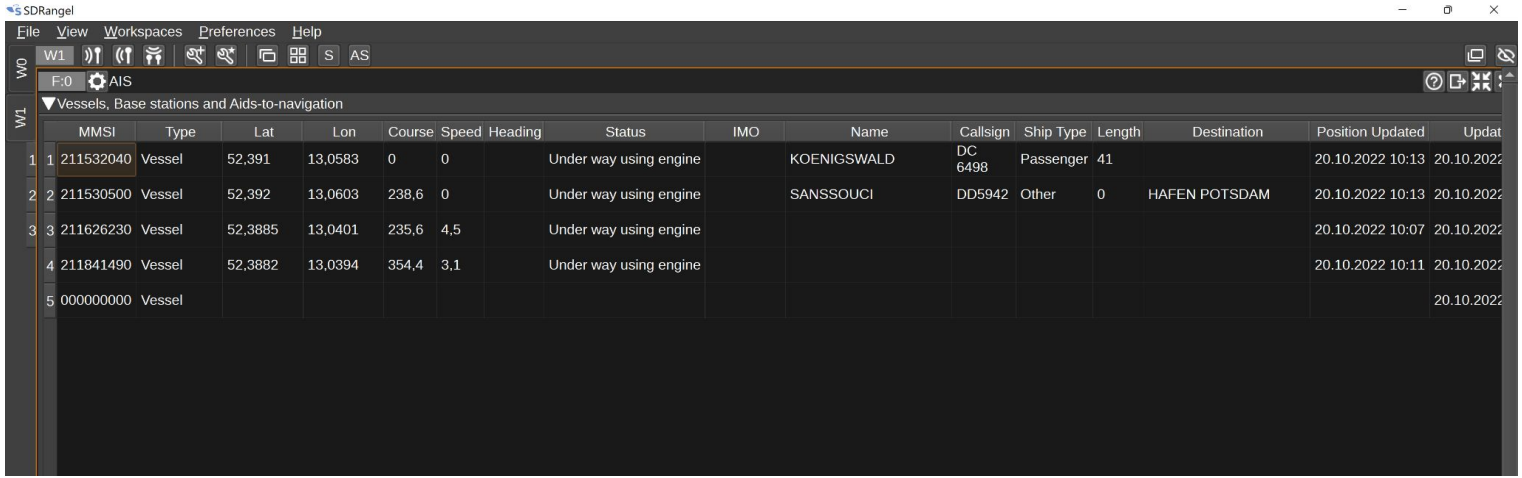
AIS heading most of the time not available!



AIS data insight

static data often not available!

relies on user input



AIS data insight related work

“AIS still lacks availability for both static and dynamic data and that the reporting intervals are not as reliable as specified within the technical AIS standard.”

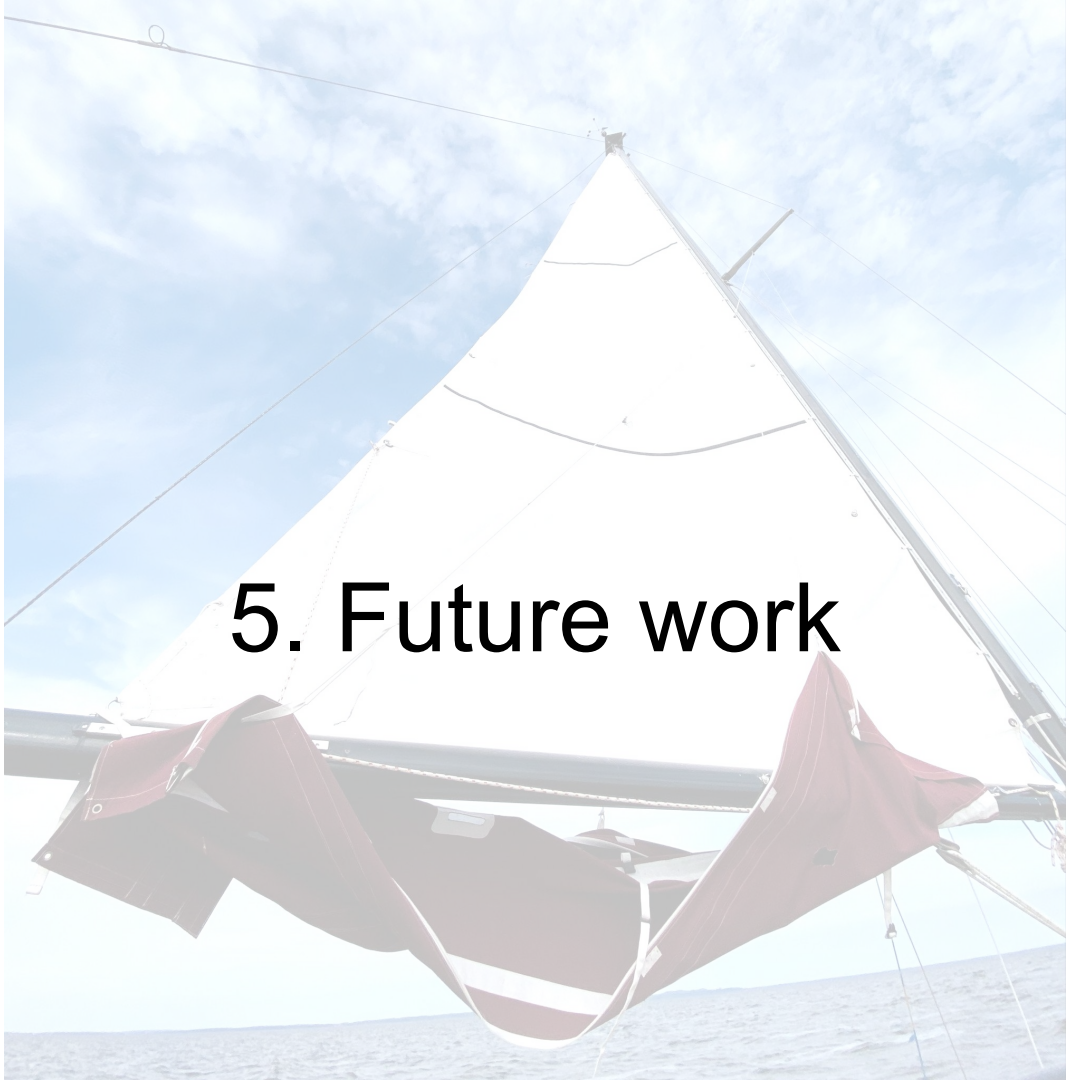
Last, P., Bahlke, C., Hering-Bertram, M., & Linsen, L. (2014). Comprehensive analysis of automatic identification system (AIS) data in regard to vessel movement prediction. *The Journal of Navigation*, *67*(5), 791-809.

“The most significant findings were that the amount of positional noise was 5.6% for sailing vessels and 0.31% for moored vessels within their specific intervals, and that missing values can reach up to 86% for static and up to 48% for voyage related AIS data.”

Emmens, T., Amrit, C., Abdi, A., & Ghosh, M. (2021). The promises and perils of Automatic Identification System data. *Expert Systems with Applications*, *178*, 114975.

Harati-Mokhtari, A., Wall, A., Brooks, P., & Wang, J. (2007). Automatic Identification System (AIS): data reliability and human error implications. *The Journal of Navigation*, *60*(3), 373-389.

Felski, A., Jaskólski, K., & Banyś, P. (2015). Comprehensive assessment of automatic identification system (AIS) data application to anti-collision manoeuvring. *The Journal of Navigation*, *68*(4), 697-717.

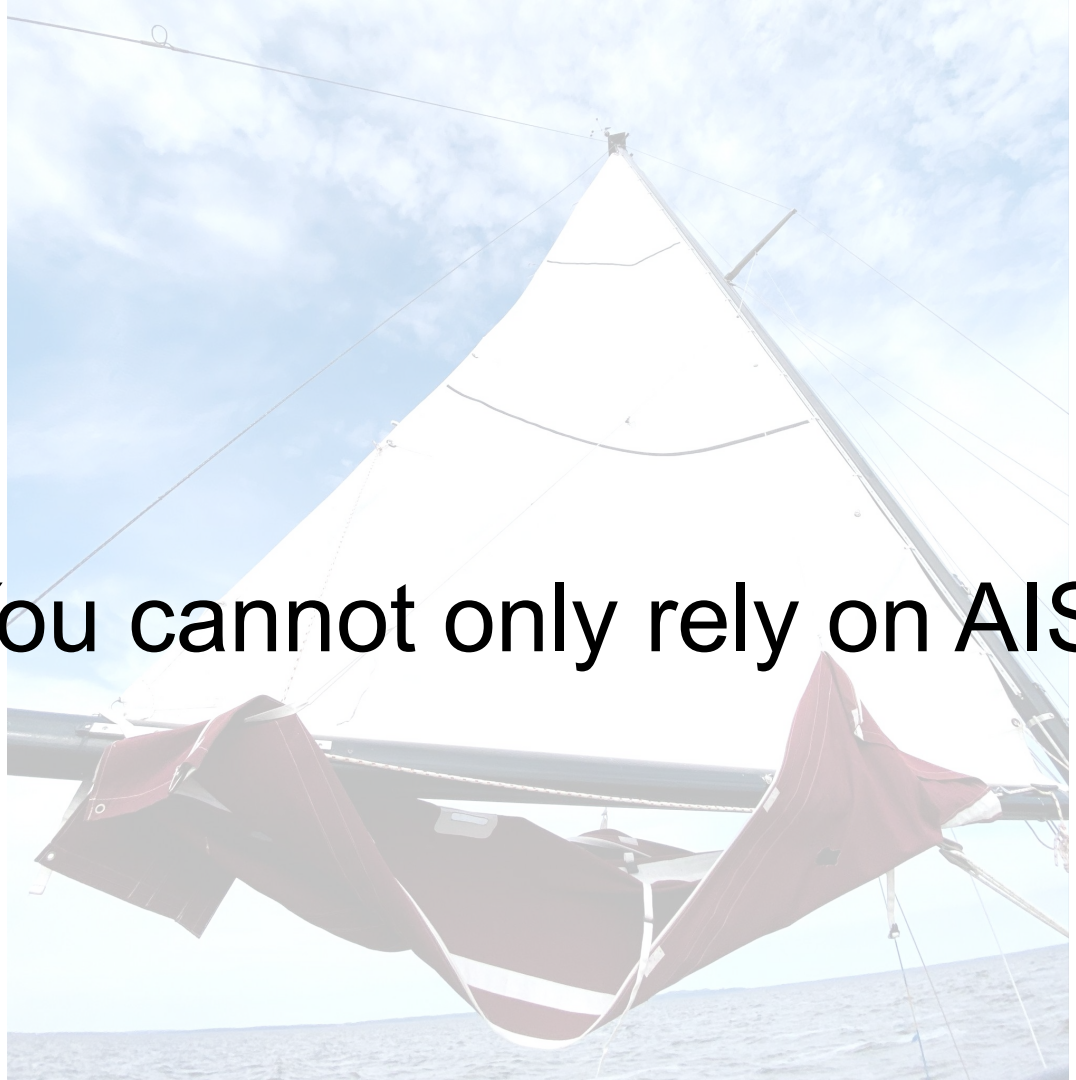


5. Future work

Future work

- real time testing on the open sea
- include “position accuracy” of AIS message into collision warning system
- include AIS SART
- fix: GPS speed is greater 0 without moving
- depending on speed more frequently collison check
- send collision data to OpenCPN to display on map
- performance optimization
- signal processing in Python to remove socket (e.g., with pyrtlsdr: https://pypi.org/project/pyrtlsdr/)

- support SDRangle https://github.com/f4exb/sdrangel/issues
- make AIS Frame Builder projekt (https://github.com/trendmicro/ais) compatible with newer GNURadio versions (use Pybind11 instead of Swig)



You cannot only rely on AIS!

Sources

https://docs.arduino.cc/learn/communication/gps-nmea-data-101 (*last accessed*: 20.10.2022)

https://en.wikipedia.org/wiki/Geographic_coordinate_conversion#Conversion_from_Decimal_Degree_to_DMS (*last accessed*: 20.10.2022)

https://images.app.goo.gl/1MvBPhitFVjhfTNZ6 (*last accessed*: 21.10.2022)

https://images.app.goo.gl/bx8Grx8cfvaZv8tT8 (*last accessed*: 21.10.2022)

https://www.future-x.de/navilock-nl-442u-usb-48kan%C3%A4le-schwarz-gps-empf%C3%A4nger-modul-20-gps-receiver-sirfstariv-l1-157542-mhz-nmea-0183-v30-wgs-84-163-dbm-p-1159632/ (*last accessed*: 21.10.2022)

http://www.coastalnavigation.com/samples/sec_3/3_grfx/heading_dia.gif (*last accessed*: 21.10.2022)

https://de.wikipedia.org/wiki/Containerschiff#Entwicklung_der_Schiffsgr%C3%B6%C3%9Fe (*last accessed*: 21.10.2022)

https://files.ettus.com/manual/page_install.html (*last accessed*: 15.09.2022)

Balduzzi, M., Pasta, A., & Wilhoit, K. (2014, December). A security evaluation of AIS automated identification system. In *Proceedings of the 30th annual computer security applications conference* (pp. 436-445).

Cruz, F. R. G., Gania, R. C. M., Garcia, B. W. C., & Nob, J. C. R. (2018). Implementing Automatic Identification System Transmitter on Software Defined Radio. 2018 IEEE 10th International Conference on Humanoid, Nanotechnology, Information Technology,Communication and Control, Environment and Management (HNICEM). doi:10.1109/hnicem.2018.8666288

https://pypi.org/project/pyais/ , resp. https://github.com/M0r13n/pyais (*last accessed*: 20.10.2022)

Felski, A., Jaskólski, K., & Banyś, P. (2015). Comprehensive assessment of automatic identification system (AIS) data application to anti-collision manoeuvring. *The Journal of Navigation*, *68*(4), 697-717.

Emmens, T., Amrit, C., Abdi, A., & Ghosh, M. (2021). The promises and perils of Automatic Identification System data. *Expert Systems with Applications*, *178*, 114975.

Sources

Last, P., Bahlke, C., Hering-Bertram, M., & Linsen, L. (2014). Comprehensive analysis of automatic identification system (AIS) data in regard to vessel movement prediction. *The Journal of Navigation*, *67*(5), 791-809.

https://images.app.goo.gl/eK8fuXtLC3xBD3sf7 (*last accessed*: 20.10.2022)

https://images.app.goo.gl/EJNxXZ2KbtRGjgyv7 (*last accessed*: 20.10.2022)

https://images.app.goo.gl/2EgPoAvbLBTt62ZB7 (*last accessed*: 20.10.2022)

https://images.app.goo.gl/usCtVMWjg4up2QUP6 (*last accessed*: 20.10.2022)

https://github.com/nawre/arpaocalc (*last accessed*: 20.10.2022)

https://en.wikipedia.org/wiki/Haversine_formula (*last accessed*: 25.09.2022)

Vujičić, S., Mohović, Đ., & Mohović, R. (2017). A model of determining the closest point of approach between ships on the open sea. *Promet-Traffic&Transportation*, *29*(2), 225-232.

Benjamin, M. R. (2017, September). Fast-CPA: A layered caching algorithm for rapid closest point of approach calculations in marine collision avoidance. In *OCEANS 2017-Anchorage* (pp. 1-9). IEEE.

Fournier, M., Casey Hilliard, R., Rezaee, S., & Pelot, R. (2018). Past, present, and future of the satellite-based automatic identification system: Areas of applications (2004–2016). *WMU journal of maritime affairs*, *17*(3), 311-345.

Harati-Mokhtari, A., Wall, A., Brooks, P., & Wang, J. (2007). Automatic Identification System (AIS): data reliability and human error implications. *The Journal of Navigation*, *60*(3), 373-389.

https://www.imo.org/en/OurWork/Safety/Pages/AIS.aspx (*last accessed*: 25.10.2022)

https://gpsd.gitlab.io/gpsd/AIVDM.html (*last accessed*: 20.10.2022)

Sources

https://tbsalling.dk/2018/09/01/an-introduction-to-ais/ (*last accessed*: 17.06.2022)

https://www.svb.de/de/ratgeber/alles-was-sie-ueber-ais-wissen-sollten.html (*last accessed*: 17.06.2022)

https://en.wikipedia.org/wiki/Automatic_identification_system (*last accessed*: 20.09.2022)

https://digitalyacht.de/wpAdmiGermdy1118/wp-content/uploads/guides/Was_ist_AIS_Digital_Yacht.pdf (*last accessed*: 17.06.2022)

https://usa.oceana.org/wp-content/uploads/sites/4/4046/oceana_ais_fin_all_hr-07_0.pdf (*last accessed*: 14.06.2022)

https://images.app.goo.gl/mGpdxv2w1dQtmkao8 (*last accessed*: 17.06.2022)

https://images.app.goo.gl/11VtcBCVwDk7svKD7 (*last accessed*: 17.06.2022)

https://images.app.goo.gl/uqWmJJ5yvotfYrNK9 (*last accessed*: 19.06.2022)

https://images.app.goo.gl/zLUKQayAFeeMg2HC9 (*last accessed*: 19.06.2022)

Series, M. (2014). Technical characteristics for an automatic identification system using time-division multiple access in the VHF maritime mobile band. *Recommendation ITU: Geneva, Switzerland*, 1371-1375.

Jia, H., Prakash, V., & Smith, T. (2019). Estimating vessel payloads in bulk shipping using AIS data. *International Journal of Shipping and Transport Logistics*, *11*(1), 25-40.

Adland, R., Jia, H., & Strandenes, S. P. (2017). Are AIS-based trade volume estimates reliable? The case of crude oil exports. *Maritime Policy & Management*, *44*(5), 657-665.

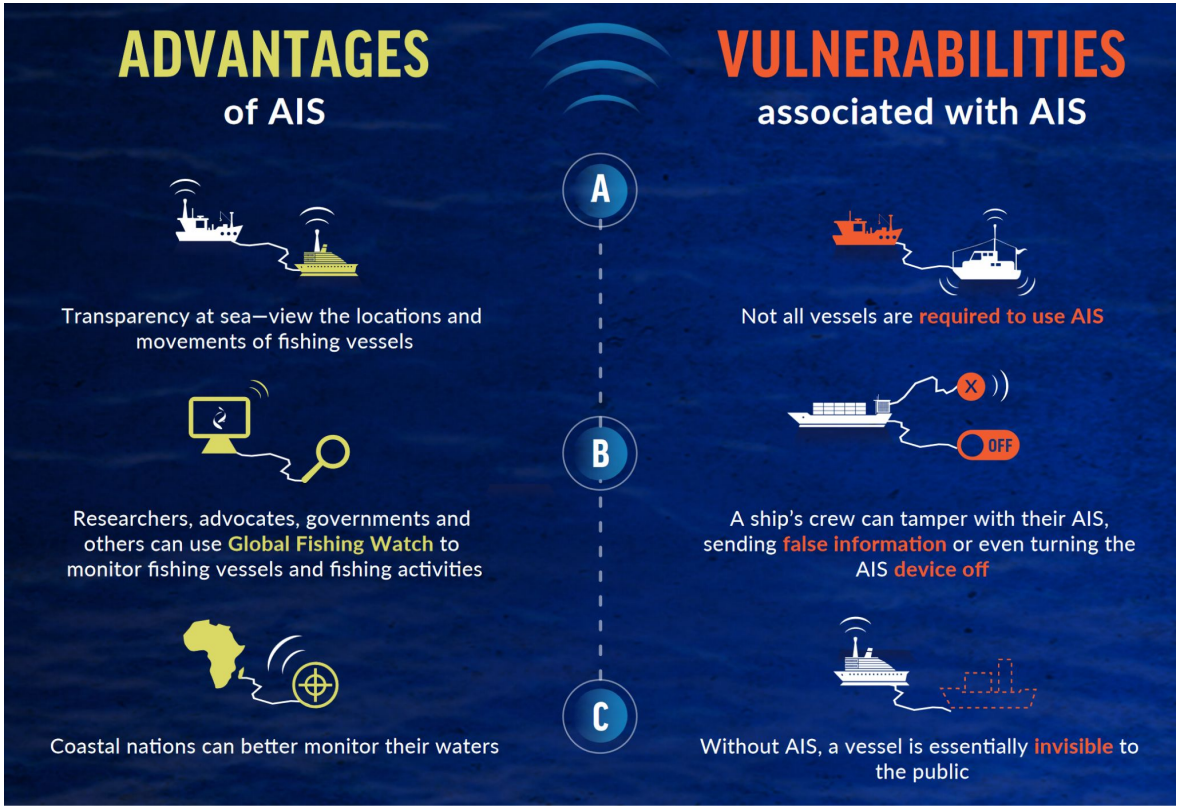
Chen, L., Zhang, D., Ma, X., Wang, L., Li, S., Wu, Z., & Pan, G. (2015). Container port performance measurement and comparison leveraging ship GPS traces and maritime open data. *IEEE Transactions on Intelligent Transportation Systems*, *17*(5), 1227-1242.

Gerritsen, H. D., Minto, C., & Lordan, C. (2013). How much of the seabed is impacted by mobile fishing gear? Absolute estimates from Vessel Monitoring System (VMS) point data. *ICES Journal of Marine Science*, *70*(3), 523-531.

Yang, D., Wu, L., Wang, S., Jia, H., & Li, K. X. (2019). How big data enriches maritime research–a critical review of automatic identification system (AIS) data applications. *Transport Reviews*, *39*(6), 755-773.

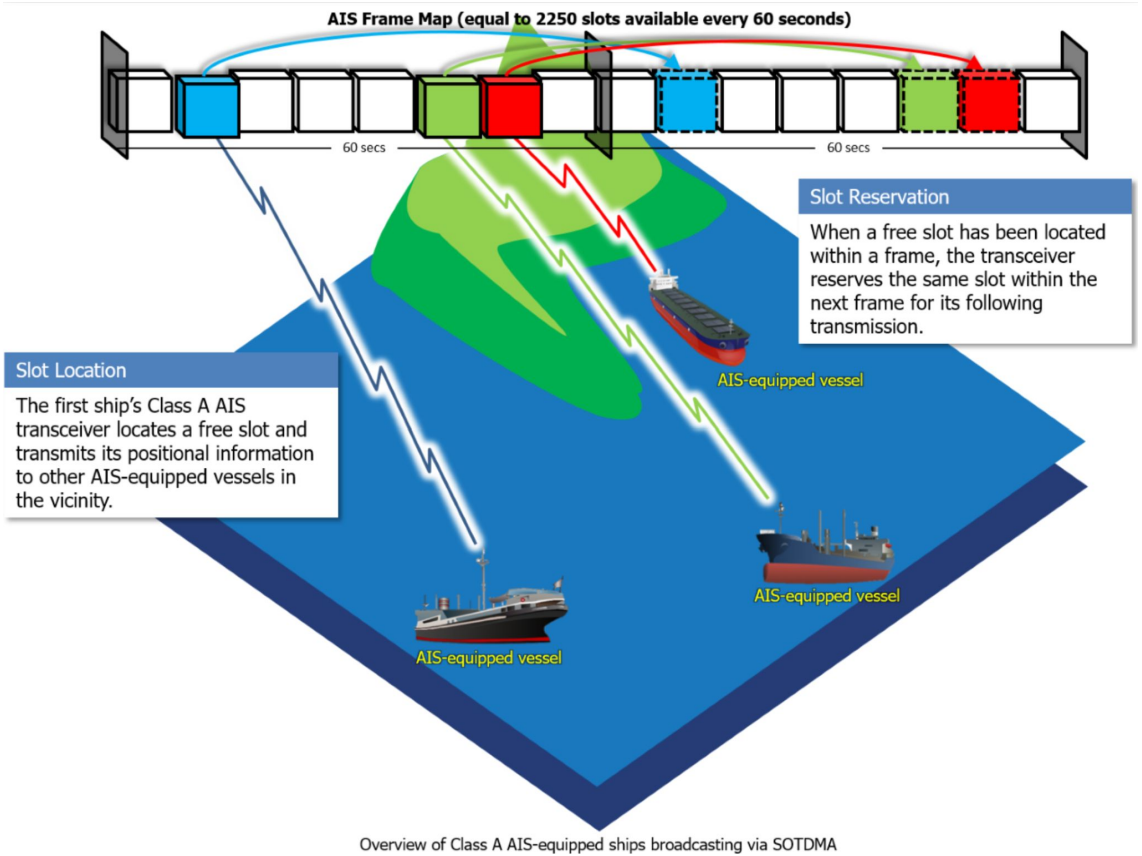
Collision detection set up

AIS pros & cons



Self Organising Time Division Multiple Access (SOTDMA)

- divides a channel into frames, which furthermore are subdivided into a vast number of time slots
- Class A AIS device will scan for available and “un-reserved” slots in the AIS slot frame map (one frame is equal to 2250 slots available in one minute intervals)
- reserve slot within the following frame for the next transmission as long as the ships using the same frame map



Overview of Class A AIS-equipped ships broadcasting via SOTDMA

https://marinfo.gc.ca/e-nav/docs/sotdma-cstdma-en.php (last accessed: 20.06.2022)