OVERCOMING SATELLITE COMMUNICATION OBSTACLES IN MARITIME HIGH TRAFFIC ZONES

spire MARITIME

CONTENTS

A WORLD IN NEED OF CHANGE

Less than 35 years ago, more than 4,000 lives were lost in the deadliest maritime disaster outside of wartime. On December 20, 1987, the MV Doña Paz, a ferry carrying far more passengers than it was designed to hold, collided with an oil tanker in the Tablas Strait between two islands in the Philippines. Nearly everyone was killed. 4,386 people died in the tragedy. Only 24 people survived.

Although there were numerous factors that led to the collision and its devastating human loss, the technologies to alert ships of other nearby vessels were limited and expensive. Ships often relied on binoculars and radio to help the captain steer clear of other ships at sea.

Shortly after GPS became available for non-military applications, it found its way into the automatic identification system (AIS) that the industry has come to rely on to help avoid collisions while also tracking and directing ships in and out of harbors around the globe.

The first iteration of AIS became a global standard for ship-to-ship and ship-to-shore communications in 2001. Terrestrial AIS (T-AIS) technology involves putting receivers in harbors and on land along the coast to work alongside ship-to-ship communication in order to track ships from the land. T-AIS is limited though and can only reach 40 nautical miles from shore, so these receivers can't track ships in the open ocean. The development of satellite AIS (S-AIS) addressed the need for AIS technology capable of tracking vessels across the globe. S-AIS allows ships to continuously transmit key data from shipboard systems via a network of satellites.

These two systems in concert with other maritime technologies transformed the shipping world. Collisions have been radically reduced, fears of getting lost at sea have been eliminated and AIS has proven extremely valuable to track and monitor maritime trade and operations.

Despite these advances, AIS still has room for improvement. Spire Global has a large constellation of satellites, many of which constantly track our oceans, but there is no feasible way to monitor every inch of the ocean, every minute of the day and night.

The other significant challenge with AIS lies in the way its data is transmitted. The signal is unlike the connection between your computer and a wifi router. In the case of a wifi signal, a secure connection is established where each specific link is discrete and independent. AIS is more like an FM radio station broadcast from each ship transmitting its direction, coordinates, and other pertinent information. But, unlike the FM dial, which is broken down into 100 different frequencies, AIS uses only two frequencies for terrestrial communication and two additional frequencies to broadcast into space.

This means that at any given time, more than 200,000 AIS users globally are using just four channels to communicate with the rest of the world.

Amazingly, the combined network of terrestrial and satellite equipment is able to track ships throughout most of the ocean. If a human being were to tune into such a cacophony of radio signals there would be no way to make sense of the noise, but the combined T-AIS with S-AIS technology developed on top of the 20-year-old AIS standard allows receivers to pull out the signal from anywhere on the planet.

TRAFFIC JAMS AT SEA

THE CONTINUAL GROWTH OF MARITIME TRAFFIC

There is a strong correlation between the growth of international trade and the number of ships at sea. With the exception of a few recent years, global trade has grown at an exponential pace since 1950, and maritime traffic has continued to increase despite recent dips in global trade. Worldwide ship traffic increased by 300 percent between 1992 and 2012, and in the first ten years of that study the total number of ships increased by 60 percent.

As the number of ships increases the amount of data required to keep track of the added traffic increases as well, and new technologies are constantly being developed to address the challenges tracking the growing number of ships at sea.

AIS IN HIGH TRAFFIC ZONES

LIMITED COVERAGE AND INFORMATION DISRUPTION

In many parts of the busiest global trade routes satellites still have trouble receiving the signal from every ship broadcasting with AIS. This is because there are so many ships traveling through the same area simultaneously that it creates a huge amount of noise. Spire Maritime refers to these areas as High Traffic Zones or HTZs.

The density of ships in HTZs is so high that when satellites fly above they receive numerous AIS message transmissions from multiple ships at the same time. Spire Maritime has identified the following areas as HTZs: The waters surrounding Europe and the Asian-Pacific countries as well as the Gulf of Mexico. New HTZs are likely to develop in the future as trade routes evolve. The waters surrounding China have been particularly challenging to monitor

The lack of adequate AIS data for HTZs amounts to an economic cost that increases every day and a risk to human life due to incomplete data.

THE HIGH COST OF HIGH TRAFFIC ZONES

High Traffic Zones are often responsible for AIS transmission gaps. When this occurs, it’s as if the ship has effectively vanished only to reappear hours later and hundreds of miles away. Sometimes these gaps are intentional, whether to evade pirates or for ships to engage in their own smuggling activities, but frequently the gaps are simply the result of a missed connection between the ship's transmitter and the satellite receiver.

The impact of these transmission gaps are felt from the shipping and fishing industries, up through the supply chain and can even impact trade between foreign nations. The large number of innocuous transmission gaps also makes it more difficult to identify dark vessels who are intentionally turning off AIS transmissions to engage in illegal activities. This in turn, increases the costs associated with enforcing the law.

It is only through accurate AIS data that shipping companies and the ports they utilize are able to choreograph the flow of ships and their cargo around the world with minimal expense and as efficiently as possible. A gap in a ship's transmission means that it could arrive when the port isn't expecting it and not ready for it to dock. Alternatively, an unexpected delay could lead to workers waiting on the clock for a ship to come in. Delivery delays are never welcome, but the uncertainty that comes from an AIS transmission gap can result in lost sales and contracts that could be salvaged with more reliable data.

THE NORTH SEA

A CASE STUDY IN THE CRITICAL NEED FOR TIMELY AIS DATA

The North Sea is surrounded by Great Britain, Denmark, Norway, Germany, the Netherlands, Belgium and France. In addition to being a major fishery, it is also home to some of the world's busiest ports, including Rotterdam, which is Europe's busiest port and the fourth busiest in the world. The North Sea connects to both the English Channel to the south and the Norwegian Sea to the north. Fishing boats, service boats for offshore industries, sporting boats, and merchant ships traveling to and from North Sea ports as well as Baltic ports must share routes on the North Sea. The Dover Strait alone sees more than 400 commercial vessels a day.

AIS data is critical for improving ship safety and efficiency in the North Sea. Because the North Sea is one of the busiest shipping traffic areas in the world, the Netherlands Coastguard continuously monitors AIS data transmitted by ships to oversee traffic patterns and provide assistance to ships as needed.

In August 2013, the Dutch Ministry of Infrastructure and the Environment modified the routes ships followed within the Dutch portion of the North Sea; a study by the Maritime Research Institute Netherlands (MARIN) was then able to use AIS data from before and after the changes to assess the efficacy of the new routes.

The study revealed that the new routes significantly reduced the number of near-collisions in almost all categories examined by MARIN. While the effectiveness of these changes shows the power of data in optimizing maritime traffic, the ongoing AIS transmission gaps mean that complete up-to-date data remains unavailable. There is far more room to fine-tune the traffic patterns along this busy shipping lane.

THE SOUTH CHINA SEA

A GROWING CONCERN

As much as one fifth of the world's products pass through the South China Sea on their way to their final destination. On any given day about 300 ships travel through the South China Sea, and the Malacca Strait — which is located between the Indian Ocean and the Pacific Ocean — is a crucial channel for international trade. Although the figure is believed to be higher today, the reported annual amount of goods traveling through the South China Sea for the past few years is 5.3 trillion dollars.

With such an incredible amount of the world's trade passing through these increasingly crowded waters the need for accurate data is more crucial than ever.

OVERCOMING LOST DATA IN HTZS

There are three possible ways to address the challenge posed by HTZs: the technology to parse through and separate the discrete signals could be improved, the AIS standards could be completely overhauled to eliminate the problem and future-proof AIS.

Finally, the number and location of AIS receivers could be supplemented to better cover and follow vessel routes in these problem areas, this is what we at Spire call Dynamic AIS™. This latter option is the most readily available solution to signal loss in high-traffic areas. By layering T-AIS, S-AIS and D-AIS™ (Dynamic) we increase granularity in positional data to support the complex processes and algorithms that many clients depend on. In one analysis we delivered:

- 25% More unique MMSIs
- Near real-time latency
- Up to six million additional AIS messages per day

SCENARIO 1

MORE AIS TRANSCEIVERS IN HTZs

Although satellites can cover a radius of about 2,500 kilometers of ocean surface, signal disruption issues necessitate fail-safe methods for ensuring the continuous and consistent collection and transmission of AIS data. Within 20 nautical miles of shore, T-AIS receivers are able to provide that necessary fail-safe, but HTZs aren't close enough to shore to be supported by T-AIS.

Increasing the total number of transceivers within HTZs is one way to address the problem, but creating a plan for how and where to position this additional equipment poses its own challenges.

While it might be possible to eventually put enough satellites into orbit to capture every AIS transmission throughout HTZs, such a massive satellite network would require an almost equally massive array of ground stations. The time and money involved in such an endeavor suggests that simply launching more satellites into orbit is not a viable solution.

Another possibility would be to attach AIS devices to high-flying balloons, similar to the way Loon is presently building its own internet provider for areas not yet equipped with broadband connectivity. While less expensive than launching a litany of satellites into space, this solution would have similar drawbacks.

A third approach would be to create a network of buoys equipped with AIS transceivers throughout HTZs. The biggest challenge in deploying such a network would involve powering the devices in the open ocean and maintaining the equipment in such harsh conditions at remote locations.

While any of the above solutions could potentially work, each of them would require deploying significant additional infrastructure to service HTZs. Building out such infrastructure would require extensive time and cost to launch.

What if the very problem — too many ships in a small area — is in fact the easiest solution. By putting AIS receivers on boats that are already traveling through HTZs as part of their existing navigational routes, the issues pertaining to finding a way to place and power additional receivers is resolved.

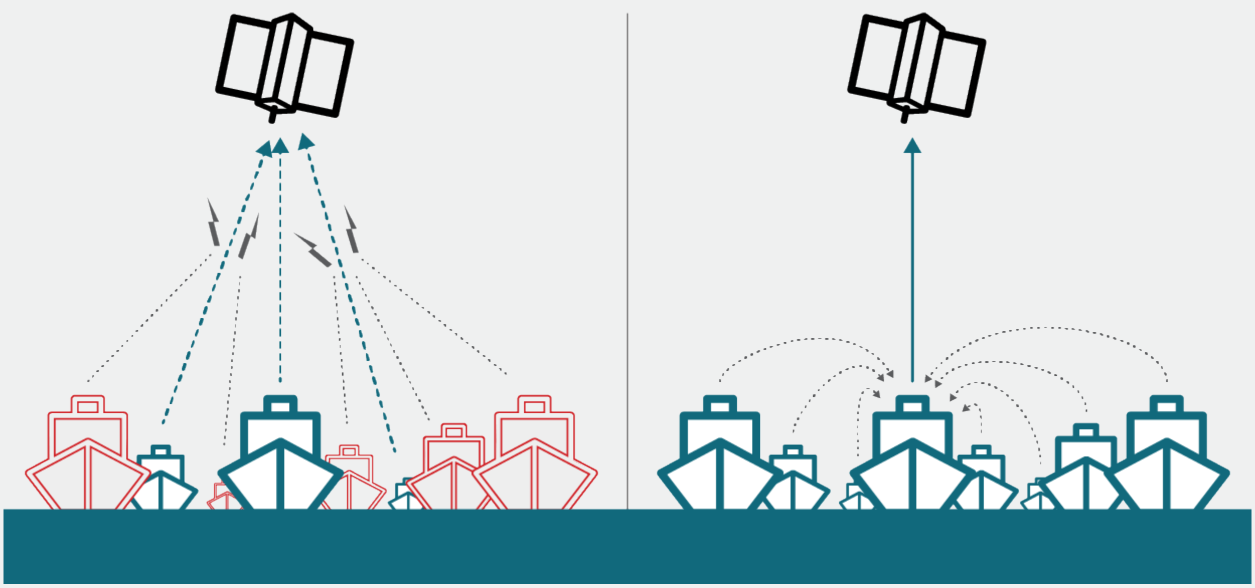

Figure 1. Spire Maritime D-AIS™ significantly improves data capture of vessels in high traffic zones by signal consolidation.

By installing receivers on thousands of ships that can interface with both T-AIS and S-AIS systems, Spire has now pioneered Dynamic AIS™ to address the challenges of tracking ships throughout the world's busiest shipping lanes.

D-AIS™ has reduced delays in receiving data in HTZs from several hours down to just 15 minutes. In a sample taken over a 24-hour period, Dynamic AIS™ delivered 56% more messages and 25% additional unique MMSIs in the South China Sea. D-AIS delivered a 17% average increase in global position updates which helped ship operators gain a competitive advantage in terms of fuel efficiency and route allocation.

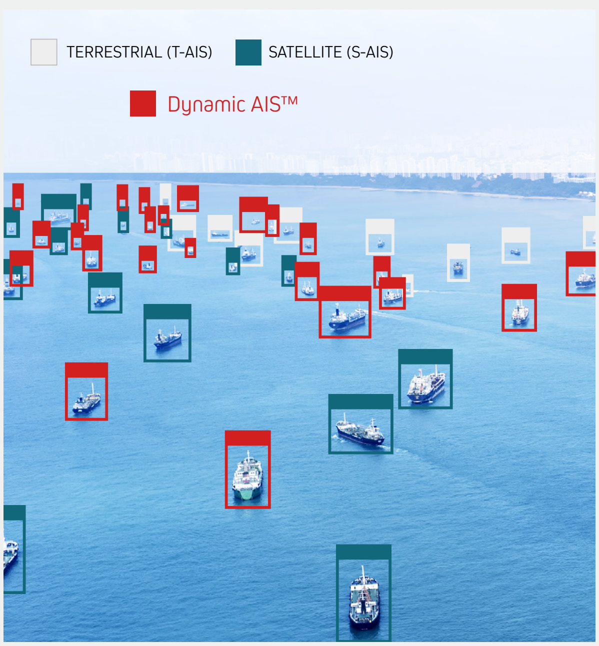

Figure 2. This simulates how Dynamic AIS™ captures vessel positions that would otherwise be lost by signal interference.

SCENARIO 2

BETTER SIGNAL PROCESSING

If you point your brand new smartphone towards the night sky, you will be able to see the stars in the photo you captured. A few years ago, it was impossible to capture such an image without very expensive equipment.

The lenses inside smartphones have improved steadily over the years, but it's the software and not the glass that makes it possible to photograph a lunar eclipse with your phone. The process of creating that photograph involves carefully analyzing the data to sort out the noise of the night sky and carefully boost the moon and each constellation in a way the human eye never could.

In a similar way, there is room to improve the ability for satellite AIS to better separate the signal from the noise. It is possible to use carefully tuned algorithms to essentially reconstruct the garbled signals from multiple ships into discrete messages while filtering out any unwanted noise.

"It is very practical to know how to visually recognize the start and finish of the AIS data by observing the waveform," writes Spire's AIS expert Andis Dembovoskis in his 2015 dissertation. "However, more advanced demodulation techniques may take advantage of different signal levels of the arriving signals, frequency shifts or other means to split overlapping messages by advancements in signal processing algorithms or antenna technologies. Thus, a question arises about signal reception probability estimate for signals containing overlaps for receivers capable of processing interfering signals."

As part of his research Dembovoskis studied the particular scenarios that cause signal interference and identified the way each impacts the data. He then identified a number of mathematical computations and algorithms to pinpoint an individual signal.

"Although there were many unexpected complications during the pathway, the goal was accomplished, showing demodulation gains for different existing and newly proposed demodulation methods applied to overlapped AIS signals," writes Dembovoskis.

The best solution to de-collision the signals would be to process the large amounts of incoming data on the satellite itself. Historically, this kind of computer processing power would be too heavy for a satellite payload, but the constant evolution of mobile processors for handheld devices means that the heavy lifting can now be done in space.

SCENARIO 3

OVERHAUL AIS

At some point every technology reaches the end of its natural lifecycle. The optical disc was developed in the 1960s. The same technology later allowed for people to watch movies with laser-discs and listen to music through CDs. Optical discs evolved into DVDs that were used to share high-quality video and data and later Blu-Ray's with even better quality video and storing even larger amounts of data.

But in 2020, the optical disc is basically dead. Wireless technology, high-speed internet and flash storage have made the technology superfluous.

While AIS is not as old as the optical disc, its origins are more than 30 years-old, and technology has evolved into something so advanced it was virtually inconceivable in 1987, the year of the MV Doña Paz tragedy.

Just as numerous technologies built on top of optical disc technology expanded its lifecycle well into the 21st century, engineers continue to develop new ways to extend the life of AIS.

One of these new developments is VHF Data Exchange System. VDES is the next step in fully digitizing the AIS radio signal. While still using legacy technology from AIS systems, VDES will increase both the efficiency and integrity of data transmitted from ships at seas.

The solutions above demonstrate that it isn't yet necessary to completely overhaul the technological underpinnings of AIS, but doing so is likely to happen eventually and it would solve the challenges of HTZs and other system limitations for decades to come.

SPIRE MARITIME

KEY SOLUTIONS TO SIGNAL DISRUPTION

We are conscious that HTZs present a big business challenge to our customers. Improving coverage in HTZs is one of Spire Maritime's top initiatives. This year, Spire has already launched Dynamic AIS™ to address the challenges of tracking ships in high traffic zones. While the initiative is still very new, it has already reduced the number of lost transmissions in HTZs. At this time 1,500 ships are equipped with D-AIS™ receivers, but Spire plans to outfit 2,000 vessels in total by the end of the year.

Additionally, Spire is working on its own signal de-collision technologies to enhance the sensitivity of it's industry-leading satellite network. Look for Spire to launch innovative products and upgrades this year to address the growing challenges in the maritime industry.

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