Dehumidification Research Trial Grant:

Final Report Part 2 – Vessel Network Connectivity Trial

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LIVECORP

THE AUSTRALIAN LIVESTOCK EXPORT CORPORATION

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1. About LiveCorp

The Australian Livestock Export Corporation Limited (LiveCorp) is a not-for-profit industry body, funded through statutory levies collected on the live export of sheep, goats, beef cattle and dairy cattle. LiveCorp is one of 15 Australian rural Research and Development Corporations (RDCs).

LiveCorp is the only RDC focused solely on the livestock export industry and works hard to continuously improve performance in animal health and welfare, supply chain efficiency and market access. LiveCorp delivers this by investing in research, development and extension and providing technical and marketing services and support to enhance the productivity, sustainability and competitiveness of the livestock export industry.

LiveCorp works across several program areas, often in close consultation with other industry stakeholders, including the Australian Government, but does not engage in agri-political activity.

LiveCorp works closely with other RDCs, research providers and industry stakeholders to achieve strategic outcomes for the industry and leverage higher returns for investments that demonstrate value for money for livestock exporters. This includes engaging with the technology start-up and innovation ecosystem to solve major industry challenges and exploit opportunities.

2. Background

1.1 Phase 1 and Phase 2 research

Australia exports sheep to and through the Middle East and North Africa region via sea, which requires voyages to travel into areas where there is a risk that ambient heat and humidity will reach high levels. Sheep also generate heat and moisture that can increase the temperature on the deck of a livestock transport vessel higher than outside ambient temperatures. The combination of these factors can increase the risk of heat stress for sheep.

To mitigate this risk, the industry currently uses high-powered ventilation systems to move fresh air through the decks and remove heat. However, there is an ongoing need to assess the efficacy of alternate, or complementary, technologies to continue making improvements to the forecasting and management of heat stress, and ultimately, to the welfare of exported sheep.

In 2018, LiveCorp began an Open Innovation project to explore technologies that could reduce the risk of hot and humid conditions on livestock transport vessels from exceeding the heat stress thresholds of sheep, and which could also provide an environment that supports acclimation to destination country conditions. In 2019, with funding from the Australian Government, LiveCorp initiated a series of trials to assess the feasibility of identified technology solutions to provide a tool in the mitigation of heat stress which may be experienced by sheep. These technologies included improved voyage route mapping, automated digital environmental loggers / sensors (temperature and humidity), noxious gas sensors and dehumidification. The first three technologies were trialled on a live export voyage from Australia to the Middle East, and the latter solution (dehumidification) was trialled on an empty vessel docked portside in the Middle East. Unfortunately, due to time constraints and vessel availability it was not possible at the time to undertake trials into improved vessel network connectivity, which was a key area identified in the 2018 Open Innovation project.

The assessment of commercial dehumidification equipment under realistic livestock export operating conditions represented the first field study conducted of its kind. A multi-disciplinary team of experts in ventilation, statistical modelling, animal physiology and engineering designed and monitored the trial, which provided a successful proof of concept for the use of dehumidifiers to reduce the heat and humidity within an empty livestock transport vessel. The trial found that without any ambient ventilation, reductions in relative humidity of up to 12% and in wet bulb temperature of up to 3.0°C were possible within 20 minutes. The data from this trial, in combination with estimates of sheep heat load generation, was used to develop a model to predict the effect of a variety of variables on the risk of sheep developing heat stress during transport by sea. The model has been used to simulate a range of scenarios beyond what was tested in the field.

The reports from the first two phases of the research conducted by LiveCorp are available at:

- Vessel Heat Stress Technology Trial Report: https://livecorp.com.au/report/1Mn1NriPYFEpsjzzcP13oR
- Vessel Heat Stress Technology Literature Review: https://livecorp.com.au/report/1CffedUrpyuWsxNHpqeYbC
- Vessel Heat Stress Technology Summary: https://livecorp.com.au/publication/1TxXvcwyhTlBzsmRBEimlO

1.2 Introduction to Phase 3 research objectives

As outlined above, Phase 2 of the project identified a range of critical lessons that were discussed between the Department of Agriculture, Water and the Environment (as the regulator) and LiveCorp. Based on advice from LiveCorp, it was recognised that the results from Phase 2 did not support progression to a trial involving live sheep on a vessel as originally planned. However, it did justify further refinement of the dehumidification model and learnings, as well as the planned investigations into improved vessel network connectivity technology.

As a result, it was agreed that LiveCorp would progress to a revised Phase 3 for the *Dehumidification Research Trial* project – entitled *Dehumidifier Specification and Connectivity Technology Analysis*. The objectives of this phase were two-fold: to identify technologies that could improve the network connectivity within, and from, a vessel to support further developments and adoption of technologies; and refine the specifications of the dehumidification required by taking the static trial (Phase 2) results and modelling them to their conclusion (detail of this Phase 3 component is included in part 1 of this project final report – *Vessel Network Connectivity Scout and Trial*).

It is noted that activities under phase 3 of the project were significantly affected by the COVID-19 pandemic, with university providers facing immediate demands to respond to changes in the delivery of their educational services, and international travel restrictions and vessel schedule interruptions increasing the complexity of trial planning.

LiveCorp would like to thank and acknowledge the contribution made by Livestock Express, Beanstalk AgTech and Scandinavian Reach Technology towards the delivery of the vessel network connectivity trial. This project was funded by the Australian Government.

3. The vessel connectivity challenge

There is increasing interest, from both industry and the regulator, in the use of sensors and smart devices to provide automated and independent monitoring and recording of conditions on livestock export vessels. However, one of the major barriers to the further use of sensors across the industry is the lack of digital network connectivity on vessels, as well as from vessels to the cloud (i.e. shore). The complex steel structure of livestock vessels presents a unique and challenging scenario for effective wireless transmissions. The current system of manually recording or downloading data from automated data loggers during a voyage not only prevents real time decision making, but is prone to error and resource intensive, taking time otherwise spent by on-board stock people attending to the livestock. The need for environmental sensors and improved connectivity on vessels was identified during the initial broad Open Innovation project LiveCorp carried out in 2018, as key enablers for the potential use of other heat stress mitigation solutions (such as dehumidification and weather routing). They are useful tools in and of themselves too, such as increasing the awareness of vessel conditions and guiding decision making.

Sensor technologies continue to rapidly improve in accuracy and reliability, as well as decrease in size and cost. They are being used on livestock export vessels to monitor and report on on-board environmental conditions. The Internet of Things (IoT) is an approach where essentially a network of physical objects – 'things' – are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over wireless signal or the internet. There is an increasing interest across all industries globally in the burgeoning capability of the IoT to automate the collection and integration of data to make better informed decisions. The lowering cost and improved technology (accuracy, reliability, ruggedisation etc) of sensors, computing power to make the data meaningful, and the increasing availability and decreasing cost of internet broadband makes IoT at sea a viable tool to assist in monitoring the welfare of livestock.

3.1 Challenge definition and design constraints

In early 2021, LiveCorp undertook a targeted challenge-led Open Innovation project to define the network connectivity problem for livestock export vessels and perform a global scout of potential technology solutions. To guide this project, a focused Working Group was established by LiveCorp composed of vessel owners and exporters identified as having an interest in supporting the trial.

Through facilitated workshops led by the Open Innovation consultants, a problem definition statement was developed to guide the global technology scout. This process challenged assumptions, interrogated the pain points currently experienced by industry, and reflected on lessons from adjacent industries facing similar challenges. From the information gathered it was apparent that while cruise liners and other maritime industries have had wireless internet in place for over a decade, replicating the same systems on a livestock vessel would be problematic. Sensors, transmitters and wires on cruise liners are relatively protected and do not have to withstand water, salt, dust, noxious gasses and livestock, unlike on livestock vessels. In addition, livestock vessels generally have more steel structures blocking wireless transmission between decks and often have some decks which have open sides.

Most vessels have adequate connectivity in crew quarters and operational locations (i.e. the bridge and engine rooms), but there is limited electrical wiring or infrastructure for wireless data transmission in the livestock decks.

To summarise, the following design considerations were identified as requirements for a successful livestock vessel network connectivity solution:

- Ability to adapt to growth of the IoT
- Real time data collection from multiple devices
- Sensors need to be rugged
- Sensors need to be low energy if power is unavailable
- Relatively easy to install and support, with no or limited 'retrofitting' of power and other cabling (which might require drilling into or otherwise affixing to steel and extra waterproofing)
- Understanding of, and preferably experience in, welfare tracking and monitoring of live organisms in transport, maritime environments, etc
- Examine enhanced opportunities for ship-to-shore communication
- Data security; retention of data ownership and use.

This activity also clarified that there were essentially two parallel elements involved in the question of vessel connectivity – the on-board (or intra) connectivity of the vessel, and the connectivity between the vessel and the shore.

The final problem statement defined by the Working Group was as follows:

> *To make data collection more valuable to stakeholders by consolidating data from multiple wireless devices across a live export vessel with speed and efficiency and then relaying the data to the cloud in an automated manner with limited manual logging.*

In effect, the core of the challenge identified was being able to transmit and consolidate data from multiple wireless devices in real time on a vessel, then relay the data to shore or to the cloud.

3.2 Global challenge-led technology scout

Based on the problem definition, the consultants conducted a detailed scout across the global technology ecosystem and other industries experiencing similar challenges to identify potential solutions.

In undertaking the scout, the consultants considered technologies against the design considerations listed above, plus the need for the solution to provide flexibility and scalability. The technology landscape revealed that in the absence of hardwire cabling, most solutions rely upon Bluetooth Low Energy (BLE) or Wifi. Each has benefits and limitations.

BLE:

- Allows sensors to communicate data without wires, Wifi, cellular or other connection
- Offers very low power consumption so battery life can be long
- Inexpensive and ubiquitous
- Latest generation BLE5 devices are more robust
- Reliable and compatible with many devices
- Cannot be used for data rates and bandwidth as high as those offered by Wifi and cellular technologies
- Unusual to be used for longer distance wireless communications, unlike cellular and wifi, except in ideal conditions

WIFI:

- Compatible devices can network through wireless access points to each other as well as to wired devices and the broader Internet
- Typically works over longer distances than Bluetooth
- Typically operates at faster data rates and bandwidth
- Wifi devices use more electric power than BLE devices, requiring a power source at additional cost
- Set up can be more expensive

It was clear that technologies to improve ship-to-shore connectivity were advancing well, with the rapid rollout of Low Earth Orbit (LEO) satellites – which improve latency, as well as new antennas and business models that are well positioned to take advantage of increasing satellite capacity. This is reducing the cost of broadband to enable it to progress on its pathway to ubiquity.

3.3 Identified technology solutions

Nearly one hundred different potential technologies were reviewed in one form or another through the global scout, with six ultimately being shortlisted as meeting the challenge statement and design considerations most effectively. The Working Group received pitches from these companies and, while recognising some potential in all of them, identified three primary candidates to proceed to possible trials. One of these technologies was focused on ship-to-shore communications, while two were related to on-board connectivity and data collection. These identified solutions were:

Kymeta

A satellite antenna that uses a holographic approach to electronically acquire, steer and lock a beam to a satellite, instead of reflecting microwaves like a traditional parabolic antenna. The flat, lightweight antennas are designed to work in high-volume markets such as automotive, maritime, and aviation. This technology was selected as an example of the ship-to-shore connectivity technologies that are now available and in competition with traditional satellite providers.

ScanReach

A Norwegian maritime company, ScanReach is the world's first wireless IoT platform for complex steel environments like vessels. Designed to enable IoT applications with wireless monitoring on vessels, it was originally developed for personal safety in the marine environment. It uses low energy radio mesh technology, with Bluetooth integration. This solution was selected as it is specifically designed for complex steel environments which were key to the design elements of the challenge. It can also be delivered as a 'plug and play' technology and asserts easy installation. The system is wireless, with no cabling required. ScanReach offers a subscription based model for its service.

Bluetooth Energy Aware Tracking (BLEAT)

A CSIRO technology using a BLE-localisation IoT algorithm to provide large scale, rapidly deployable real-time tracking of assets. CSIRO advises it can be adapted to work with almost any sensor to capture information on humidity, ammonia, ventilation and more. It has already been commercialised in the mining and construction industries.

4. Vessel connectivity trial

4.1 Overview

Following the Open Innovation scout and identification of technology solutions worthy of trial, discussions progressed to scoping the trials for the three identified technology providers to validate the respective solutions for potential broader industry application.

While the intention was to run all three trials, COVID-19 caused significant disruptions, delays and logistical challenges. In the end it was only possible to trial one solution in the available timeframe and budget of LiveCorp's grant. This included logistical factors such as uncertain and changing shipping schedules, delays in transporting equipment internationally and to clear customs, international travel restrictions and quarantine inhibiting movement of technical personnel, changing insurance policies, and global supply shortages of technology hardware and materials. An assessment was made to focus on the ScanReach Mesh Network system as the product was commercially available and the provider was able to provide timings and quotes within the constraints of the grant period. Further, the equipment was able to be deployed quickly, transported to a location to align with the available vessel voyage schedule, and would be simple to install (by the vessel crew if required). These factors were important in terms of simplifying the complexity created by COVID-19 protocols within Australia and globally.

LiveCorp continued discussions with the remaining two selected providers in the event that their technologies could be trialled within the available grant period. These discussions are ongoing and LiveCorp hopes to invite them to take part in a future trial program in early 2022.

The objective of the selected trial (ScanReach) was to deliver a proof-of-concept of the capability, feasibility and operation of the technology to offer an effective intra-vessel connectivity solution. This would involve wirelessly collecting temperature and humidity data from sensors placed throughout an operating livestock vessel, and transferring it in real-time to a central point for visualisation on the vessel and on land.

LiveCorp established a partnership with one of the largest livestock shipping companies servicing the Australian livestock export industry, and is grateful to Livestock Express for its partnership, support and contribution to the success of the trial.

4.2 The connectivity solution – Mesh Network technology

The technology provider selected for the trial, Scandinavian Reach Technologies (ScanReach), is a Norwegian based company which developed the world's first wireless IoT platform specifically for complex and confined steel maritime environments (vessels, oil rigs, etc). With origins in personal safety and monitoring in these maritime environments, the ScanReach Connect platform uses a Mesh Network technology. This is effectively a series of small radio mesh 'nodes' placed throughout the vessel that act as a wireless network to transfer data via SUB GHz radio frequency to a central point (gateway computer) on the vessel. The mesh nodes integrate with automated environmental sensors via Bluetooth to capture and transfer the data. Once centralised, the data can then be visualised on the system user interface in real time and uploaded to the cloud via the ScanReach platform using a single internet connection. The Mesh Network itself does not require internet access and works purely offline to collect and aggregate the data for use on the vessel. A diagram of the system can be seen below.

The gateway computer is an industrial computer holding the system software and the point for aggregation and storage of the data. It is connected via a cable to a single node, called 'the root node', which is the end point of the wireless network. The data, via the user interface, can be viewed in real time on a digital device linked to the gateway computer (either on board or on land through the cloud). The gateway computer is connected to the vessel's computer server so as to integrate with the vessel's satellite communication system and uses standard protocols to communicate with the mesh nodes (i.e. DHCP/IP configuration). For the data to be uploaded to the cloud (and viewed remotely on land), or to receive system software upgrades, the gateway must be connected to the internet. The gateway computer must be accessed over HTTPS/SSL to allow for authentication, encryption and decryption of data uploaded to the cloud.

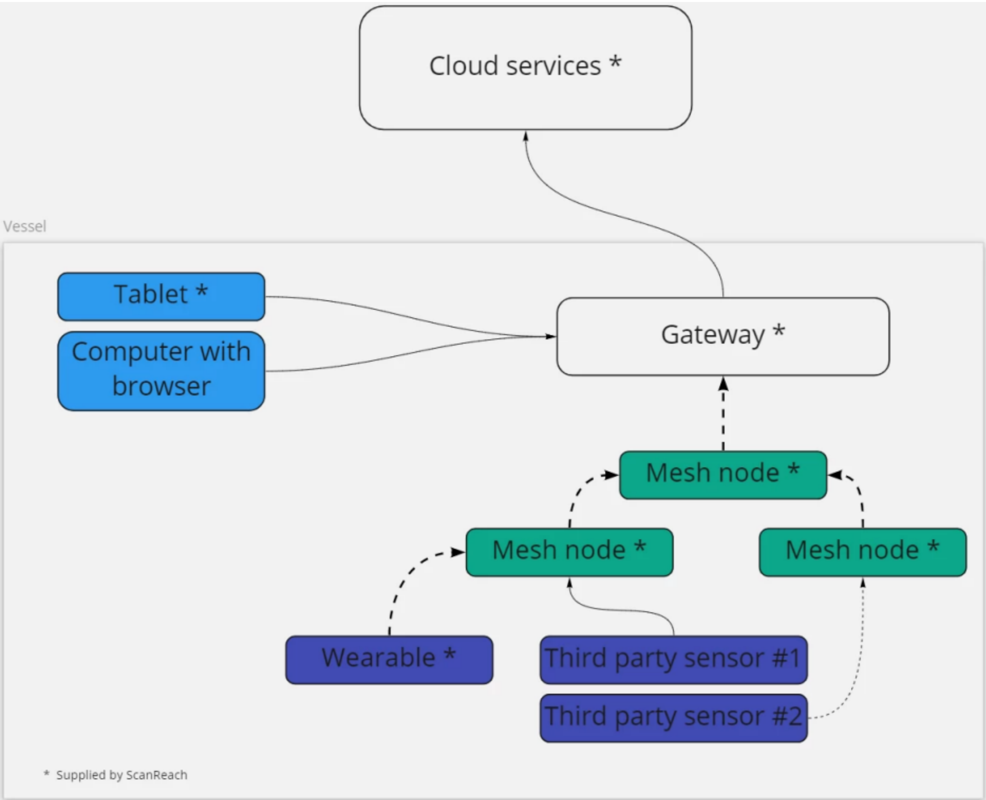

Figure 1. ScanReach Connect IoT system

Figure 2. ScanReach's small radio mesh node devices (20x52x60mm)

4.3 Methodology and trial parameters

The solution providers involved in the trial were requested to observe the broad trial parameters outlined below:

- Each trial will be run over at least two voyages – one with and without livestock on board.
- Livestock will be required on the vessel for one leg of the journey as the physical density of the animals will likely affect signal attenuation.
- The solution provider will work closely with the vessel owner's nominated project manager, CTO and/or others as nominated and agreed with the vessel owner.
- Any personnel required to board the vessel to install equipment for the trials, or for any other reason, will do so only with the prior approval of the vessel company and adhere to all COVID-19 requirements and restrictions from the vessel company or any relevant authority.
- The solution provider will provide all implementation instructions and any training of vessel staff where required.
- The training and implementation instructions provided should be documented by the solution provider.
- The trial will be run over all livestock decks of the vessel.
- The data to be collected and transmitted during the trial will consist of wet bulb temperature, dry bulb temperature and relative humidity measurements taken from across the vessel for the entire voyage(s).
- The data needs to be able to be received and visualised using a tablet, mobile device and/or computer on the vessel, and a computer on land.
- The data must be provided via an easy-to-read digital interface on the electronic devices provided.
- The solution technology must operate separate to the vessel's regular technology and communications operation system.
- The solution must be able to operate without relying on the vessel's power supply (e.g. using battery power).
- The vessel's power supply may be utilised for equipment in some areas of the vessel with agreement of the vessel owner (e.g. the central computer at the bridge).
- The solution provider will provide all hardware required, including wireless MESH nodes, in order to service connection to the environmental sensors.
- There should be at least five environmental monitoring sensors positioned across each livestock deck of the vessel in a grid pattern (where possible), so as to mimic a likely real-world setup of the solution as well as test any locations that would be expected to be challenging from a connectivity perspective.
- The solution provider may supply its own environmental sensors, noting the need for them to be ruggedised to at least Ingress Protection 6 and preferably 6-7, or have the capacity to be made so, and certified to be safe for marine use.
- The sensors should be positioned on the vessel to be out of reach of the animals to prevent ingestion.

- A nominated wet bulb temperature threshold must be observable. The threshold selected is not considered harmful to animals on the vessel, but will guarantee evidence of the capability to build in automated signal and alert functionality if required in the future.
- There will also be a ‘traffic light’ system of alert indicators that allows the observer to monitor conditions, that remains consistently green if the environmental conditions are within acceptable limits and red if it reaches or exceeds the nominated threshold.
- The solution must provide evidence of consistent and reliable signal strength across, and between, the decks where the sensors are placed for the extent of the voyage.
- Critically, the solution must demonstrate consistent and reliable real-time supply and aggregation of data from all the sensors to a central point (electronic device/computer) on the vessel and accessible by nominated shipboard staff for the extent of the voyage (departure to destination).
- The solution should be able to demonstrate live feed of data via satellite to members of the trial team on shore.
- The solution provider must be available to provide online support for the trial so that personnel on board can be offered assistance, if required.
- During installation, the solution provider must not drill, puncture or otherwise physically disrupt any part of the vessel in affixing any hardware required for the solution.
- The solution provider must advise of the amount of data it believes will be required for transmission off the vessel to ensure any vessel data/bandwidth limits are not exceeded.

4.4 Trial design and preparation

It was decided that for the purposes of the trial testing the ScanReach Connect technology, 25 environmental sensors would be installed throughout the vessel. Three sensors would be placed across the smaller decks and up to seven sensors placed across the larger decks. ScanReach adapted its standard setup design according to the requirements of the vessel, trial parameters and chosen location of the sensors.

The layout design of the solution on the vessel used a criss-cross configuration of the sensors and nodes taking into consideration the layout of the decks, obstacles interrupting the ‘line-of-sight’ between nodes, placement of devices out of reach of livestock, and potential ‘dead spots’ on decks. For this trial it was also important that the setup was completely wireless and did not require direct power supply (i.e. that it could operate on battery power). This is because accessible power supply on livestock decks is very limited or non-existent, and it is important that the technology solution tested is flexible enough to adapt to all vessels. In the case of the trial, relying on battery power also reduced the work required for installation.

ScanReach initially did some work to try and integrate its system with a brand of environmental sensors reasonably commonly used by industry. However, in the timeframe available this was not possible, and an alternate third-party environmental sensor was used to collect dry bulb temperature, wet bulb temperature and relative humidity during the trial.

Figure 3. Third-party digital environmental sensor

A corresponding 25 mesh nodes were placed across all livestock decks of the vessel in a similar configuration to the environmental sensors. Four mesh nodes were also placed in the decks between the highest livestock deck and the bridge. This was necessary to achieve a constant connection through the mesh network to the gateway computer on the bridge.

Placement of the nodes in a mesh system is, to a certain extent, flexible – the governing factor being the level of radio signal strength between the mesh nodes and sensors to transfer the data. However, on vessels, steel walls and other obstacles influence the radio signal significantly. The environmental sensors communicate with the nodes via Bluetooth, which operates at a shorter distance (up to tens of meters with clear line-of-sight) and does not handle obstacles as well as the Mesh Network system itself. Where there is clear line-of-sight, radio signals between the nodes can reach hundreds of meters. This was taken into consideration with the final recommended system setup.

While one mesh node can pick up signals from several sensors at once, for the trial, a density of one mesh node to every sensor was chosen to ensure connection throughout the whole vessel and redundancy in the network. It was also agreed to place each mesh node with its lithium battery inside a watertight IP67 junction box to protect them from the dust, water and salt present in the deck environment.

ScanReach tailored its existing software and wireless mesh protocols to integrate the chosen third-party environmental sensor and implemented a temperature/humidity threshold for automated alert functionality. For the purposes of the trial a temperature and humidity threshold equivilent to the combined Temperature Humidity Index of 83 was set. This threshold was selected as a low level that would confidently be exceeded during the voyage to enable the effective testing of the automated alert capability of the system. It is not considered to reflect any scientific threshold in relation to environmental conditions. On the user interface, sensors measuring conditions below the nominated threshold remain green and those above would turn red. The user interface itself was tailoured to display the blueprint of each deck of the vessel with different coloured dots to show the location of the installed mesh nodes and sensors, as well as the current temperature and relative humidity at each sensor.

4.5 Trial setup and installation

The connectivity network solution was installed by a ScanReach technician, assisted by personnel from the vessel company, while the vessel was at anchorage in Singapore in late May 2021 for maintenance work. The installation was completed within half a day.

The mesh nodes and environmental sensors were positioned on the decks according to the configuration design outlined above (also see Figure 8 below). The mesh nodes were attached within their watertight IP67 junction boxes to railings along the roof, and the environmental sensors were attached to metal poles or railings also near the roof using heavy duty velcro. This approach to the installation made it very quick to perform, requiring no hard wiring, access to power outlets or physical alteration to the vessel. The roof position was chosen to ensure that there was no risk of ingestion by the livestock and that there was good signal strength between nodes (line-of-sight and no interference from livestock).

When installing the gateway computer in the vessel's bridge, some issues were experienced initially in successfully integrating it with the vessel's satellite communication system. However, this was quickly resolved. The intention was to use a tablet device to monitor the data via the user interface, but due to limited Wifi on board it was chosen to set up one of the vessel's computers instead.

At the completion of the installation the system was successfully tested for full operation.

Figure 4. ScanReach mesh node installed within an IP67 junction box for protection

Figure 5. Installation of environmental sensor

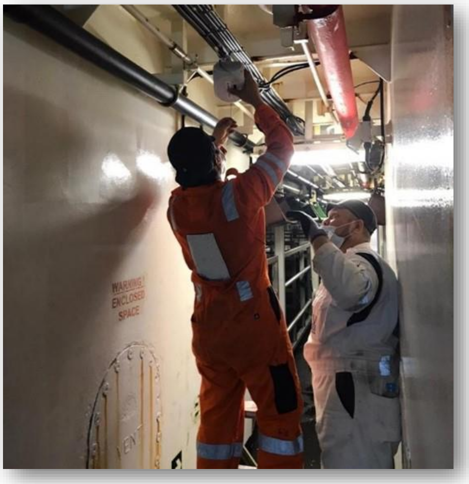

Figure 6. Installation of a mesh node inside an IP67 junction box

Figure 7. Installation of a mesh node inside an IP67 junction box

The image below shows a screenshot of the ScanReach user interface displaying the real-time environmental conditions on each deck of the vessel. The small blue and yellow dots are the mesh nodes, the large coloured circles are each sensor displaying the temperature, relative humidity and combined Temperature Humidity Index at each one. As discussed above, all sensors displayed as green are below the nominated temperature / relative humidity threshold. Additionally, the user interface provides the functionality for users to select individual nodes to see their specific battery level or signal strength.

Figure 8. ScanReach user interface displaying location of the mesh nodes, environmental sensors and the real-time environmental conditions at each sensor

4.6 The trial – with and without livestock

Once the equipment was installed and its operation tested, the vessel (without livestock on board) departed Singapore for Darwin, Australia. In Darwin, cattle were loaded onto the vessel before it travelled five days to a South East Asian livestock export market. Following discharge in market, the trial was concluded and the equipment was taken down.

Operation of the connectivity system was tested and monitored during both legs of the voyage to observe any impacts due to the presence of the livestock. The only noticible impact of having the livestock on board was a minor reduction in signal strength on one deck. As the equipment was not permanently installed, this was easily resolved by the crew slightly moving a few of the nodes on this deck under direction from the technology provider. Full signal coverage across the deck and between adjacent decks was restored for the remainder of the trial.

In addition to observing the environmental conditions on each deck at a particular point in time via the user interface, the full log of data was synced and saved to the cloud and made available to the trial team throughout the voyage. Examples of these data logs are provided below, depicting a 48 hour period of the temperature, relative humidity and Temperature Humidity Index of each sensor.

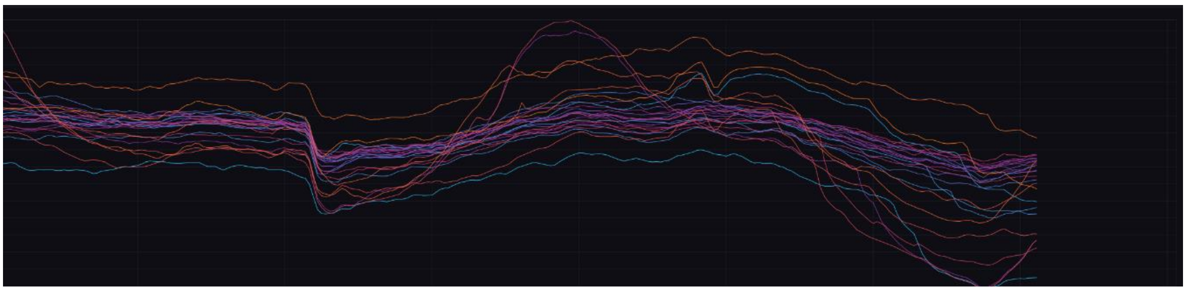

Figure 9. Temperature data log of a 48 hour period

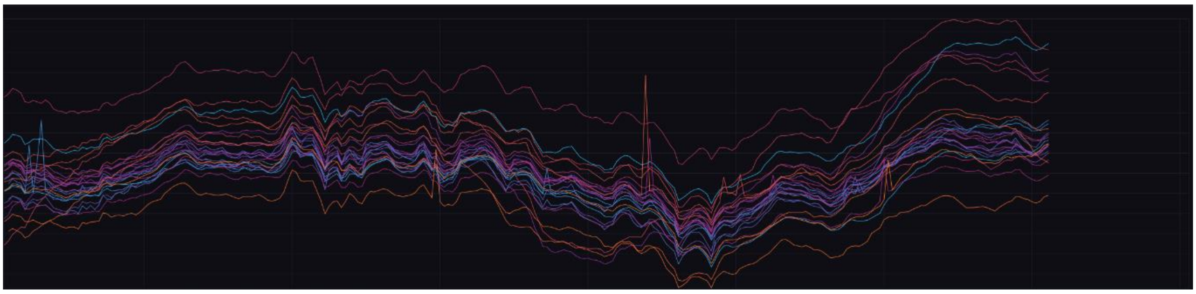

Figure 10. Relative Humidity data log of a 48 hour period

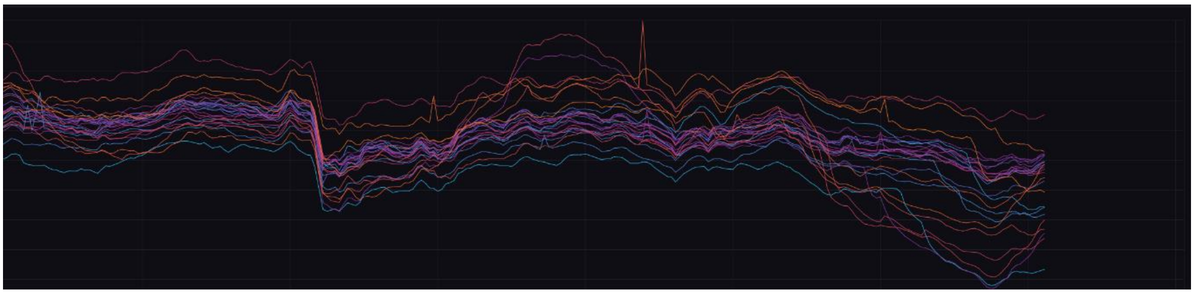

Figure 11. Temperature Humidity Index data log of a 48 hour period

During the trial, several operational activities were performed on board which impacted on the measurements taken by the sensors. For example, to protect the equipment while the vessel was cleaned thoroughly for biosecurity purposes, the mesh nodes and sensors were taken down for a short period of time and placed together in a cupboard. The effect of this can be clearly seen in the centre of Figure 12 below which shows the full aggregated temperature log from the entire trial period. It is also important to note that for the first few days following installation (while the vessel was empty), maintenance work was conducted on the vessel's ventilation system, causing significant variation and volatility in the measurements recorded during that period.

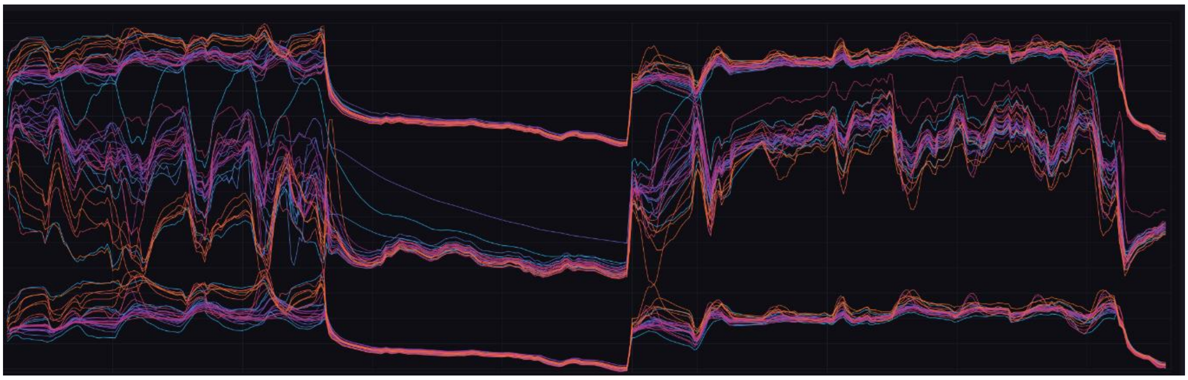

Figure 12. Temperature Humidity Index data log of a 48 hour period

The following graph shows the relative humidity recorded by three sensors on the same deck throughout the extent of the trial.

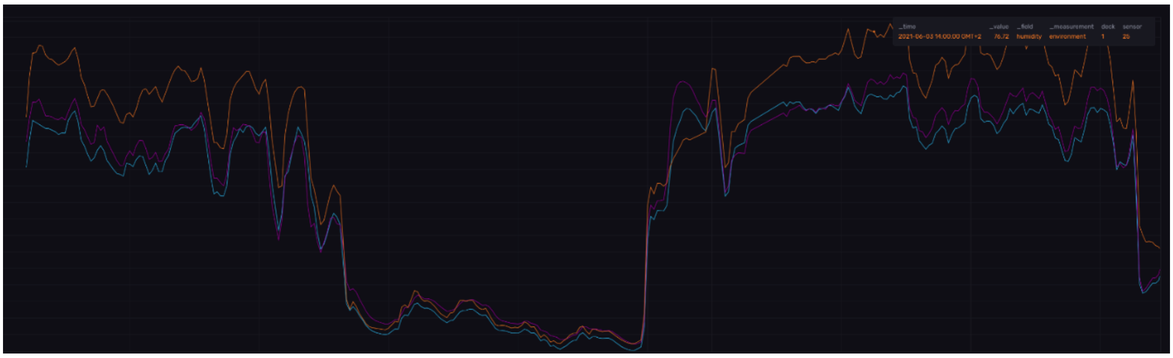

Figure 13. Relative Humidity data log from one deck for the extent of the trial period

A detailed log of the operational activities on board was recorded by the vessel crew and is set out below. A clear correlation is evident when comparing with the changes in environmental conditions displayed in Figure 12.

- 31 May – Re-installed all nodes and sensors in cargo holds after cleaning
- 01 June – Switched on all ventilation fans prior to loading in Darwin
- 01 June – End of sea passage to Darwin
- 01 June – All fast to Darwin
- 01 June – Commenced loading cattle
- 06 June – End of sea passage to market in South East Asia
- 06 June – All fast to market in South East Asia
- 06 June – Commenced discharging cattle
- 07 June – Collected all nodes and sensors in cargo holds in preparation for hold washing.

During the trial the nominated automated alert threshold was set at a low combined Temperature Humidity Index of 83. As mentioned above, this threshold was selected purely for the purposes of testing the automated altert functionality, and not as an indicator of heat stress inducing conditions for livestock. As can be seen from the user interface screenshot below, the altert functionality worked successfully once the nominated threshold was triggered, turning the corresponding sensor red.

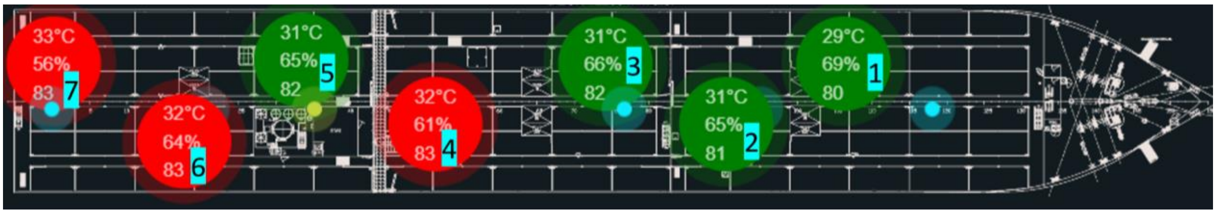

Figure 14. ScanReach user interface displaying succesful operation of the automated alert functionality when the nominated Temperature Humidity Index threshold was exceeded at individual sensors

4.7 Results and discussion

During the trial there were very few interruptions to the operation of the Mesh Network system, and it remained operational throughout the trial both without, and then with, livestock on board.

The system achieved real-time and automated collection of deck environmental conditions, and visualisation by the crew on board and personnel on land.

Early in the trial voyage, poor battery connection at one node was detected, leading to a reduced redundancy in the network for a short period of time before this was rectified. Additionally, some periods were observed where there was limited/poor internet connection from the vessel causing remote access (from land) to temporarily fail. Importantly though, during these times when the external internet connection was lost, continuous collection of and access to the data on the vessel itself was not interrupted.

As predicted, the presence of livestock on the vessel had some noticeable impact on the performance of the Mesh Network system; however, it was minimal. There was a minor change to the radio signal strength between a few of the nodes which was easily overcome by moving them slightly closer to a stairway.

During the trial, the system on the vessel transmitted approximately 4.4MB of data to the cloud every 24 hours, from the 25 environmental sensors (collecting measurements once per minute). This data load is directly related to the number of sensors and type of data being collected. It was confirmed that the data was available via the user interface for remote access in close to real time.

4.7.1 Considerations for future permanent solutions

If livestock export vessel companies were to look at implementing a permanent commercial Mesh Network solution, the technology provider recommended consideration of a few minor alterations to the trial setup. This includes connecting the mesh nodes to fixed power, if possible, to remove the need for the crew to replace the batteries periodically. If fixed power is not feasible, an alternate larger battery with a life of up to six months could be used. The placement of the sensors and nodes could be slightly optimised; however, the setup used for the trial is considered to reasonably accurately represent a permanent commercial installation. Nevertheless, in a commercial roll-out every installation would be planned and tailored specifically to the vessel based on its size, layout and power supply. In addition, having a few spare nodes on board would be useful in case any devices needed to be replaced during a voyage. Finally, a slightly stronger internet connection than what was available for the trial would be beneficial, particularly during the installation phase to ensure that the network quality can be properly assessed, and modifications made if necessary.

In terms of installation, the opportunity for a site pre-inspection would provide value to pre-determine the exact position for each node and sensor to be installed. This would likely reduce the time required for the installation. Installation on a larger or more complex vessel than used in the trial would likely require longer, as would undertaking electrical work to provide fixed power.

The technology of environmental sensors and data loggers is progressing rapidly and new devices are on the market all the time. The third-party sensors used in the trial met their purpose and provided a cost effective and accurate feed of data; however, in practice they were not regarded to be sufficiently ruggedised to offer a permanent option for livestock vessels.

ScanReach offers a subscription-based service model where technical support is offered and firmware/software updates for the system (gateway, mesh nodes, etc) are automatically downloaded and deployed to the system through the gateway computer when connected to the internet.

4.7.2 Next steps

To build on the success of the proof-of-concept trial, LiveCorp would like to undertake more extensive vessel connectivity trials through a range of scenarios. In concept this would involve conducting the same trial with ScanReach, but under more intense parameters to test the full capacity and the optimised setup of the Mesh Network solution. For example, the next trials would take place on a larger and more complex structured vessel, over a longer voyage, integrating other more complex or data intensive IoT devices, and with potentially fewer nodes per sensor. LiveCorp understands that the ScanReach Connect system is typically able to integrate with both wireless and wired third-party sensors. Wireless Bluetooth based devices with open protocols are preferred; however, wired integration over MODBUS is possible.

Undertaking a second series of trials would also enable LiveCorp to test the alternate connectivity solutions that were identified through the initial Open Innovation phase of the project to compare intra-vessel connectivity technologies and trial those offering improved ship-to-shore connectivity.

5. Conclusion

The objective of the trial was to:

- deliver a proof-of-concept test of the capability, feasibility and operation of the ScanReach Mesh Network connectivity technology
- automatically collect data from multiple wireless devices across a livestock vessel and transfer it in real time to a central point for visualisation on the vessel and remotely.

The technology solution successfully met all aspects of this objective for the full extent of the voyage, including with livestock on board.

The trial demonstrated the ease with which the solution can be implemented, requiring only a few hours to install. The user interface provided a clear and efficient access point to observe and monitor the deck conditions in real time for timely decision making both on the vessel and remotely during a voyage. A complete log of the data was also stored for future analysis if required. In addition, the included 'traffic light' automated alert system for when temperature/ humidity conditions exceeded a nominated threshold, worked effectively and demonstrated a valuable functionality of the system.

More extensive trials were recommended to validate the outcomes of this trial and test the full capacity of the technology.

Digital automated monitoring is already becoming critical to the operation of most industries that have large capital maintenance or time and environmental sensitivity. The need for and reliance on IoT and automated monitoring on vessels will only continue to grow and the applications it enables will only increase. It is clear from the success of the trial that the capacity and flexibility of the ScanReach system is such that it can provide the trunk infrastructure to enable vessel owners and exporters the opportunity to integrate a variety of digital or automated monitoring technologies as needed in the future (noting the need for further trials to test more complex scenarios). This removes a significant barrier to the continued digital transformation of the industry and supports the sustainability of the trade.