Protecting Livestock Using Network Biosecurity Technology

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Introduction

Track and trace, or contact tracing, when combined with various control measures, is shown to be highly effective at reducing disease transmission and minimizing economic impacts compared to other disease control strategies[1]. With the constant threat of devastating diseases such as African Swine Fever (ASF), Foot and Mouth Disease (FMD) and Avian Influenza (AI), and highly infectious production limiting diseases such as Porcine Epidemic Diarrhea virus (PEDv) and infectious bronchitis (IB) in poultry, contact tracing as a regular management practice either undertaken at a company or industry level has a vital role to play in protecting the health and welfare of farmed livestock and poultry.

Paper-based systems exist for the purpose of tracing people, (i.e., visitor logbooks), and truck logistics systems (i.e., GPS) make vehicle tracking possible. However, neither of these systems is designed for the purpose of track and trace, and as a result neither can work in real time. For a system to efficiently mitigate disease spread, the track and trace capability should work in as near real time as possible. Manual visitor logbooks are only filled in (if at all) 33.3% (See Racicot 2012)[2] of the time. When an attempt to fill them in has been made they are often hard or impossible to read, are not confidential as subsequent visitors can see who has been there previously and are not human or livestock pathogen safe as they are touched by every visitor. They are therefore not reliable and unsuitable for the purpose.

Vehicle tracking logistics systems are designed to be truck centric as they are programmed to monitor driver behaviour, fuel consumption and other physical attributes related to truck performance and efficiency. The other issue with vehicle GPS logistics systems used with semi-trailers is that the trailers are not tracked. Once they are dropped off in a collection yard the trace history from the original cab GPS system is lost for that trailer. As soon as another truck picks it up the trailer becomes associated with a completely different tractor and therefore its movement history is impossible to track. The devices tested in this project enable the tracking of trailers even when they are being pulled by a different tractor.

This latter point is very important. Livestock and poultry live-haul trucks are the highest risk fomite in the industry. This is because they carry live animals which - as demonstrated by Alban and Boklund (2008)[3] - are the highest risk carriers of pathogens. The trailers are often heavily contaminated with manure, other animal secretions, skin, hair, contaminated fodder and bedding, etc. This makes livestock trailers extremely high risk if they are not completely cleaned and disinfected between loads, a vital step that is often missed or carried out in haste and therefore ineffectively, due to time pressures of logistics management. This creates a massive risk of pathogen transfer and without full trailer traceability a huge, if not the biggest gap in the track and trace process.

[1] https://onlinelibrary.wiley.com/doi/10.1111/tbed.14334

[2] Racicot, Valiiancourt et al U. Montreal 2012.

[3] Qualitative ranking of disease transmission routes in relation to the risk of transfer of pathogen. (Alban and Boklund, 2008)

For disease movement monitoring, the system needs to be specifically designed in a property centric manner which allows for temporal and spatial analysis of people and vehicle movements relative to the index property and infected premises. When tracing is undertaken after the fact, a significant amount of manual work is needed to determine and analyze the connections between potentially affected premises and the subsequent epidemiological analysis that will help shed light on how to better manage future outbreaks.

The CFIA report into the 2015 Avian Influenza outbreak in British Columbia is a good example of how long, without the aid of near real time track and trace, it takes to implement track and trace and undertake the subsequent epidemiological review[4] . In this case movement tracing began on December 1, 2014 after the first farm was quarantined. It ended on February 20, 2015[5]. This highlights the failings of trying to use a paper-based system for track and trace during a disease outbreak. Real-time track and trace is therefore crucial for faster response times in order to reduce disease transmission and minimize negative impacts. Electronic visitor recording wherein the records are housed in a central database would immediately solve this problem. Such systems exist and Farm Health Guardian is the industry leader in this technology.

Tracking trailer movements are a different problem. Because trailers are not connected permanently to a power source there is a need to have a battery back-up system for times when the trailer is parked. This may be either be when the trailer is parked awaiting its next run or it could be when the trailer is in lairage awaiting its turn to be pulled into the processing plant. It could also be that there is no easy way to connect the tractor power to a permanently fixed GPS Device on the trailer which means the trailer device must have sufficient battery power to enable it to monitor movement accurately for long periods. Three ways exist to make this work reliably:

1. Recent developments in battery life have made vehicle track and trace for this purpose possible.
2. Solar powered GPS devices
3. Devices that seamlessly connect into the trailer system and which carry battery back-up.

Track and trace system proven effective for one major branded food company

Maple Leaf Foods recognized Farm Health Guardian in their 2020 and 2021 Sustainability Report as the company's digital farm traceability and biosecurity technology partner. The report states that "Farm Health Guardian is a complete, real-time disease spread mitigation platform that tracks personnel and vehicle movements in coordination with the health status of barns or geographic areas. In the event of an animal disease incident, time is of the essence. This system allows our team to impose movement restrictions and conduct biosecurity trace-backs in near real-time, reducing the risk of disease spread and saving hours of work compared with traditional paper-based methodologies."

[4] https://inspection.canada.ca/animal-health/terrestrial-animals/diseases/reportable/avian-influenza/disease-incidents/avian-influenza-in-british-columbia-2014/eng/1475593889073/1506003977167?chap=0#s7c6
[5] https://inspection.canada.ca/animal-health/terrestrial-animals/diseases/reportable/avian-influenza/disease-incidents/avian-influenza-in-british-columbia-2014/eng/1475593889073/1506003977167?chap=0#s14c7

Farm Health Guardian conducted field testing of track and trace technologies in vehicles that do not have GPS logistics (e.g., trailers and service vehicles) making them impossible to track without a device of some description. Field testing occurred over the course of several months, and as such we were able to evaluate performance over several seasons and extreme temperatures. Among the characteristics we evaluated were:

- Ease of installation,
- Durability,
- Accuracy,
- Performance under a variety of different conditions and.,
- Potential to integrate with a cloud-based tracking system capable of integrating information from multiple tracking systems (basically does the device have an open API). The Farm Health Guardian system has this capability and was used for the trial.

BACKGROUND – WHY TRACK AND TRACE IS SO IMPORTANT

Economic Impacts of Disease

The negative economic effects of animal disease outbreaks are staggering:

- Food and Mouth Disease (FMD) = $30-50 billion[6]
- Avian Influenza (AI) = $600 million in just one province[1]
- African Swine Fever (ASF) = $50 billion[7]

The 2021-22 AI outbreak has exacted a huge toll on the poultry sector globally. In the U.S. as of early as May 2022, 37 million chickens and turkeys in 32 states have died as a result. The current epidemic threatens surpass the last major outbreak of H5N2 and H5N8 in 2014-15, which cost an estimated USD $3.3 billion in direct production losses and an additional $610 million in federal government cost for response activities on premises (69 percent of total public expenditures) (Elam, 2015, Johnson et al., 2016),

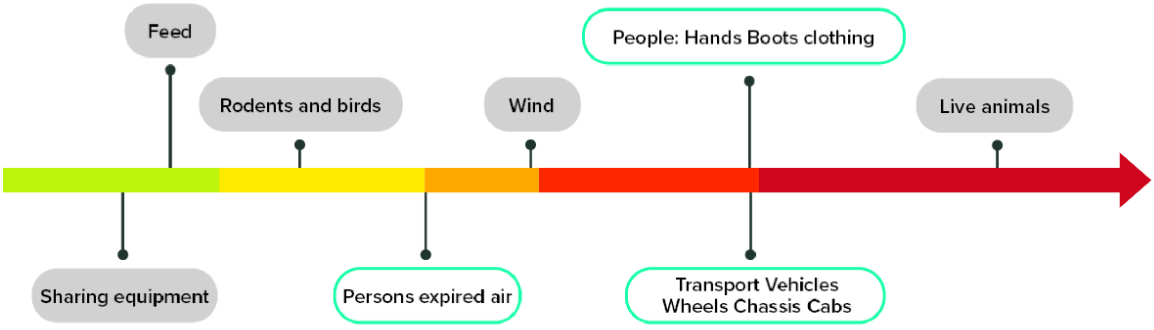
The Canadian Food Inspection Agency (CFIA) reported 1.82 million birds on farms had been culled or died from the disease, also as of early May[8]. These numbers have demonstrated that industry is not well enough prepared to prevent a repeat of the 2015 disaster.

[6] https://www.ahwcouncil.ca/pdfs/AHC_Gaps%20Analysis%20Report_February%2013_EN.pdf
[7] https://thepigsite.com/articles/new-economic-study-african-swine-fever-outbreak-in-the-us-could-cost-50-billion#:~:text=New%20economic%20study%3A%20African%20swine,of%20ASF%20in%20the%20US.&text=The%20study%20replicates%20the%20impact,%2450%20billion%20over%2010%20years.
[8] https://www.realagriculture.com/2022/05/avian-influenzas-toll-on-canadian-poultry-farms-exceeds-1-8-million-birds/

What Does the Research Say?

1. Disease transmission occurs mainly through movement of animals, people & vehicles

The figure below shows the relative importance of the different pathways of pathogen transmission between farms[9]. As shown, the disease transmission pathways increase in importance from lowest to highest risk moving from left to right along the graphic. Feed and sharing equipment are the lowest risk and animal to animal transmission is the highest or most important pathway for disease spread.



According to tables published by Iowa State University College of Veterinary Medicine, fomites are the main mode of transmission of all the major poultry[10] and swine[11] diseases. Do we know enough about our transport and people connection networks to be able to predict spread and prevent such significant losses?

Understanding people and vehicle movements within a network is essential to prevent and control spread. An analysis of the network between poultry farms in Korea during the Highly Pathogenic Avian Influenza (HPAI) outbreak of 2016-2017 confirms that to prevent and control disease spread, it's essential to understand people and vehicle movements within a network of farms[12]. This will help minimize negative impacts of disease by targeting restrictions to the highest risk premises and not farms at lower risk. The researchers go further to recommend that animal health authorities should investigate the real-time vehicle movement data to assess the farms at risk and prevent further spread. Common send tells us that some farms are higher risk than others based on biosecurity practices. One common denominator that we can monitor and validate is the movement of people and vehicles between properties at risk. Most other biosecurity practices are inside the farm gate, and can not be validated to the same degree of accuracy. However, fomite movements can still be accurately recorded.

While migratory bird flyways make a region vulnerable to HPAI, once it is introduced, people and vehicle movements between premises are likely responsible for its spread. Dr. David Swayne, a leading U.S.

[9] Qualitive ranking of disease transmission routes in relation to the risk of transfer of pathogen (Alban and Boklund, 2008)
[10] https://www.cfsph.iastate.edu/Assets/routes-disease-list-poultry.pdf
[11] https://www.cfsph.iastate.edu/Assets/routes-disease-list-swine.pdf
[12] https://www.nature.com/articles/s41598-021-03284-x

Department of Agriculture veterinarian, says that "There have been multiple studies across the world that would say transmission of virus from farm to farm is through fomites in most situations, and movement by air (as being sucked in by the ventilation and distributed by wind), is a much less common occurrence".[13]

An analysis of the African Swine Fever (ASF) outbreaks in China which recently appeared in the peer reviewed journal *Viruses* identified people as the main source of disease spread. Almost half (46%) of the ASF outbreaks appear to have had the virus introduced by people and vehicles.[14]

The importance of understanding vehicle movements and the networks between farms was validated by Yang et al. Their simulation results reveal that including the truck movement (indirect contact) can significantly exacerbate the disease spread in the system, compared with equivalent scenarios that only consider animal movement. For example, the median number of infected producers is 7 in scenarios that only consider animal movement vs. 72 in scenarios that include both animal and truck movements[15].

The length of time a truck or a loading/unloading area remains contaminated is affected by the ability of the pathogen to survive on fomites, environmental factors such as temperature and the frequency of the disinfection operations. An analysis of the impact of pathogen transmission by fomites showed that people and vehicles do have significant influence on duration of the contamination period and the resulting extent of disease spread and size of the epidemic[8]. This highlights the need for a deeper understanding of indirect transmission by fomites, and the need for experiments to more accurately quantify the contamination period and probability of indirect contact transmission.

2. Disease transmission risk increases with frequency of visits to a farm

True risk can be expressed using the probability formula: P= 1-[1-p]n where p = risk of transmission route and n = frequency of transmission route)[16]. Assume that the risk of disease introduction into a herd or flock through feed delivery is 1 out of 1,000. For example, the feed truck may be carrying porcine epidemic diarrhea (PED) on its tires when it comes to the farm. If feed is delivered every week, what is the annual risk that the feed truck will introduce the pathogen? Repeated weekly, a single event with a 1/1,000 risk becomes a 1/20 risk. The event has a very small risk when it occurs only once, but becomes a much higher risk when it occurs frequently.

In another example real time data taken from the Farm Health Guardian system truck visits to a specific farm were monitored. An analysis of the data revealed that a single truck visited the farm 3 times in 7 days (Aug 20, 24 and 26). Using the calculation and assuming three visits per week, this truck poses a 15% risk of bringing a disease pathogen onto the farm per year. In this example, frequency causes risk to

[13] https://www.wattagnet.com/articles/35999-avian-flu-can-be-transmitted-by-air-but-focus-on-fomites?v=preview

[14] https://www.mdpi.com/1999-4915/13/12/2552/htm

[15]https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7567383/#:~:text=Since%20contaminated%20trucks%20can%20travel,the%20scale%20of%20epidemic%20spreading.&text=Distributions%20of%20numbers%20of%20infected%20producers%20and%20cattle%20agents%20removed.

[16] The formula P= 1-(1-p)n is the statistical formula to calculate cumulative proportions or probabilities based on the binomial distribution (binomial distribution derived by Jacob Bernoulli is the correct statistical distribution for 0/1 events (eg. 0 = no introduction: 1 = introduction).

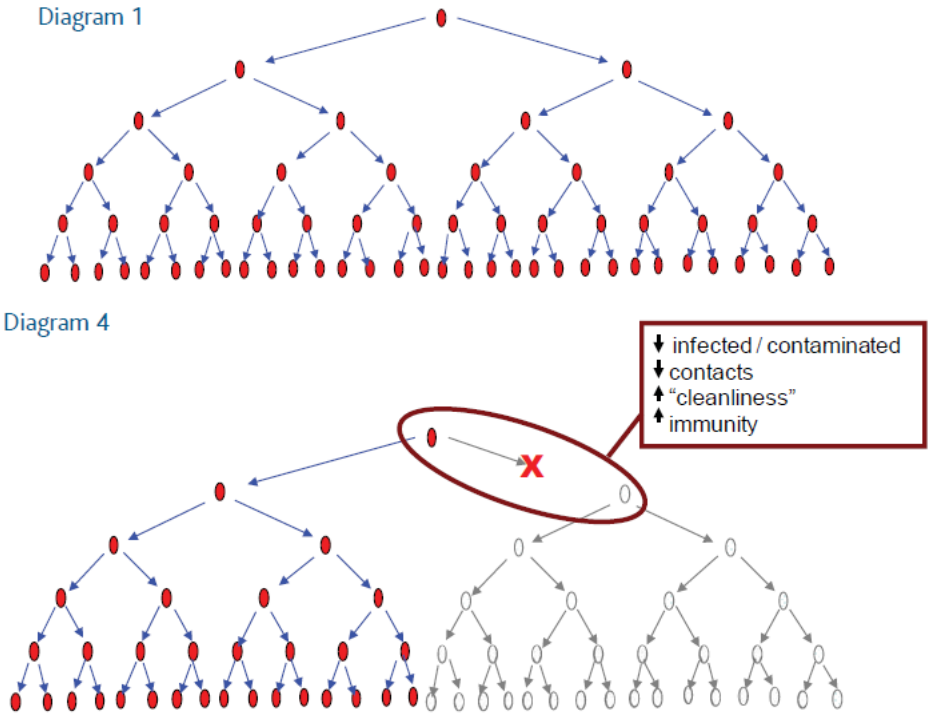
increase by 150 times, from a 0.1% risk from a single visit to 15% due to multiple visits. The repetition increases this risk to a level that is important to consider when prioritizing biosecurity measures.

The frequency of the repetition of an action is very important. While the everyday event may be low risk, repeating it frequently results in it becoming a much higher risk over time.

3. Early disease detection significantly reduces disease spread

The ability to immediately (i.e., in real time) understand people and vehicle routes/connections and the transmission risks will help stop the spread and impact of disease. Research in Korea confirms this point: "A good monitoring system should provide fast tracking of disease outbreaks and assist decision makers in understanding and explaining disease dynamics and spreading patterns[17]."

The figures below illustrate how stopping disease at even one node of transmission will have a dramatic impact (Source: Dr. Bruce McNab, Animal Health & Welfare Branch, Ontario Ministry of Agriculture, Food & Rural Affairs):



[17] https://www.frontiersin.org/articles/10.3389/fvets.2021.676661/full

4. Contact tracing the best intervention for controlling swine disease spread

Mathematical modeling was used to show the effectiveness of different control strategies on African Swine Fever (ASF). The study used real animal movement data to simulate the propagation of two ASF strains among more than 13,000 pig farms[18]. The researchers showed that contact tracing was the best intervention compared to any other control strategies in the model. Contact tracing resulted in 95% disease control, outperforming radius-based quarantining. Of all the scenarios tested, contact tracing always resulted in the best control from both a disease control and an economic standpoint.

Control strategy	# infected farms quarantined	# healthy farms quarantined	% control of transmission
15 km quarantine around index farm	14	63	85%
15 km quarantine + system-wide quarantine of all farms in the same company*	16	2100	89%
15 days of contact tracing	18	12	95%
30 days of contact tracing	18	28	99%

Combining contact tracing with a 15 km quarantine zone plus system-wide quarantine, did not show any significant increase in control of transmission compared with contact tracing on its own. It did, however result in 2100 healthy farms being unnecessarily quarantined. The economic consequences of quarantine are often devastating for individual farms and companies. Movement permits are required for feed deliveries and to bring animals in or out. Product can not be shipped and exporting countries may be forced to a standstill.

For example, a leading broiler chicken company in the UK affected by the current HPAI outbreaks is losing £15,000 per week (approximately $24,000 CAD) because they are banned from exporting. That's £60,000 per month or $95,500 CAD! The company has not been infected by HPAI but the 10 km quarantine zones in the area require that they get movement permits and cease exporting product.

[18] https://onlinelibrary.wiley.com/doi/10.1111/tbed.14334

RESEARCH PROJECT – Devices Tested and Results

Goal: To test and validate vehicle and trailer tracking technologies in real agricultural environments for the purposes of disease control and mitigation in livestock.

Method:

Over a period of 8 months, we tested five different technologies, each was tested for a minimum of 6 months. The technologies tested were all bought 'off the shelf' with the exception of the RFID system which was developed in-house.

The technologies tested were as follows:

- Battery powered GPS devices – some augmented by solar power
- Wired GPS devices,
- Bluetooth low energy (BLE) devices,
- Medium Range Radio-frequency identification (RFID) and,
- Long-Range Local Area Network (LoRa LAN).

143 devices tested and 278 properties in Ontario were involved in the trial. Please see Appendix A for a full list of participants.

Note: LoRa LAN devices were tested in Saskatchewan due to their unique telecommunications network. Funding for this part of the project was provided through the Canadian Agri-Food Automation and Intelligence Network and the Canadian Agricultural Strategic Priorities Program.

Devices were purchased from independent suppliers. Each was given a unique identifier for ease of recognition in the field based on the User, his or her company and the vehicle carrying the device. Some vehicles were equipped with multiple device types to enable comparison.

Fitting instructions were provided to the user or user organization and where it was deemed necessary FHG provided field support in order to ensure that the devices were correctly set up and working. Some devices were mounted externally on trailers and some were placed 'in cab'. Those externally mounted devices were carefully placed to ensure they received the most extreme treatment likely to be experienced in the field. For example, these devices were subjected to:

- hot and cold high pressure washing
- Thermal Assisted Drying and Decontamination (TADD) at >75°C for 15 minutes,
- Being mounted on the exterior of trailers in Northern Manitoba during winter they were also subjected to temperatures below -40°C and with the windchill factor probably lower than -50°C.

It is important to note that for accurate GPS data flow the battery devices should have a clear 'view' of the sky and therefore need to be mounted externally on the trailer. This does not seem to be such an issue for powered devices.

The vehicle movements which were recorded in the FHG system and those recorded on the device company dashboards were compared. This comparison enabled a detailed analysis of times of entry and

departure from premises recorded on both systems and the accuracy of those measurements appearing in the FHG system. Where possible these records were also compared with the participating company records of entry and exit from the properties by the vehicles. While company records of dates of movement were available it was generally only possible to get approximate entry and exit times so these data were not used in our final analysis.

General observations:

None of the devices currently on the market are designed specifically for use in a livestock trailer tracking capacity. It was therefore not easy to identify those that could withstand the rigours or requirements of use in an agricultural setting and particularly in relation to being used for pathogen tracking.

Manufacturers recommendations, while accurate, are not always the best guide for producers and agricultural transporters looking to identify devices that are suitable for farm and livestock trailer transport use. For example, some devices with IP ratings of IP67 (no ingress of dust and full immersion in water up to 30 mins at a depth of 1 meter) might sound good but will not keep water out if subjected to pressure washing. Likewise, any devices rated as being “water resistant” are not sufficiently sealed to withstand normal farm vehicle operations. If as an operator you can be sure never to have to hose down or pressure wash a vehicle then IP67 rating might suffice but for livestock transport monitoring they are not recommended.

All of the systems tested have very good dashboard facility. The dashboards come with good maps, ability to group and view devices within the system or individually, good historical data for retrieval. These were all attributes one would normally associate with a fleet tracking system. The devices we tested that were battery powered clearly did not have the ability to link to the vehicle operating systems and did not perform any of the vehicle monitoring systems offered by powered systems connected though OBDII ports for example. This was not the purpose of the pilot, so it was not a measurement of fitness for use that we measured.

All devices were straightforward to fit especially the battery powered devices and manufacturers instructions on fitting were clear.

Signal (ping) frequency significantly affects battery life. All devices had the ability to increase or decrease the number of times the device reported movement to the system (pings). They could also be set to only report starts and stops. See discussion on battery powered devices and signal frequency (including start and stop events) below.

To enable the ability to utilize multiple systems within one monitoring system (FHG) all of the systems we selected had an open API for external system integration. API documentation was variable and some more difficult to implement than others and in two cases had to be corrected by the device supplier before it could work.

All of the companies we trialed had a different method of charging for the systems and these need to be carefully compared before purchase as some have separate API and cellular data fees.

Results of technologies tested:

Battery operated devices, signal frequency and 'start-stop' settings.

We examined several different battery-operated GPS devices. Of these we identified a few that were well suited for use in an agricultural setting. One of these included a solar panel to recharge the batteries. In general, these devices are only designed to provide a single location check in per day. Although they can do more regular monitoring of location, we found that battery life, even with solar augmentation, dropped from years to weeks if they check in anything more than stops and starts. There is always a trade-off between battery life and the frequency of signals emitted by the device (pings). Recording GPS position is not particularly battery intensive, however, the draw on the battery when the device sends the information to the cloud whether by wifi or cellular is high. Manufacturers will generally claim very long battery life (5 years plus). This is only true when the device is set to send a signal at the minimum level, often only one ping per day. Ideally, for real time track and trace, in order to provide the highest level of accuracy we need constant monitoring. Constant monitoring drains battery power very quickly and current battery technologies do not allow for long term, constant monitoring. When comparing battery life between devices it's important to factor in frequency of reporting or pings. If a vehicle is moving more than a few times per week the battery life will be substantially shorter than the manufacturer's claim. In this case and if possible, a wired device is recommended.

Although monitoring 'start and stop events' sounds simple, it is not. It relies on the accuracy and sensitivity of an accelerometer and a complex algorithm built-in to the device. The devices vary in sensitivity and accuracy depending on manufacturer. 'Stops' are relatively straightforward but can be misleading. The motion stops and the device internal system sends a report (ping). But in some cases, we noted that even stops can be problematic. With 'Starts' the problem arises because most accelerometers are set to 'kick-in' at certain ground speeds. It is often the case that large vehicles leaving a property do so very slowly and the accelerometer does not 'kick-in' until the vehicle is well outside of the property and moving at speed. In a system that relies on starts and stops to occur within geofence coordinates which delineate a property boundary, if the 'start' occurs outside of the geofence no exit is recorded on the central system. Likewise, if the 'stop' signal is sent as the truck slows down just before the truck enters the geofence, as has happened on a number of occasions, then no entry is recorded either. The geofencing is critical to avoid having every start/stop location such as traffic lights or traffic jams or even just turning a corner reported to the system as these would be erroneous entries into non-existent sites.

As noted above the draw on the battery when the device sends the information to the cloud whether by wifi or cellular is high. There are some recent developments in battery powered devices that 'store' the location information in the device and only send it once or twice per day. In most cases while this is not real time it would suffice for Track and Trace purposes post identification of an emerging disease. Such information woulfd be sufficient for post outbreak analysis such as that undertaken by industry or researchers or, in the case of notifiable diseases, government.

If real time is essential and where possible from a notification of potential contamination perspective, we recommend powered devices.

Wired devices & logistic systems

We examined several devices that are wired directly into a vehicle or trailer. These are slightly more involved to install, but with clear instructions can be completed in a few minutes. They are more costly but allow for real time location of the vehicle or trailer at all times. Devices installed in the cab of a vehicle can be connected to the OBDII port. If the port already contains a device – often used for insurance purposes, splitters are available so that more than one device can be connected simultaneously. For larger vehicles including semi-trailer tractors, adaptors are available for most makes of vehicle.

These systems do not independently track the trailer and so the OBDII port devices are generally not useful for articulated vehicles (semi-trailers) where the tractor regularly pulls different trailers. They are however ideal for single body trucks and service and delivery vehicles.

We have tested one (1 only) device that is automatically powered from the trailer. It was selected for its ease of being fitted as opposed to other trailer mounted powered devices which are more difficult to fit and generally take some expertise. This device has a battery back-up system lasting 3 months should the trailer be disconnected from the tractor. If the trailer is disconnected from the tractor it is clearly not moving which means limited signal (once per day) from trailer device to the central system is sufficient for tracking purposes and the life of the battery is sustained. This system has all the attributes of the battery GPS devices we tested. It is being used year-round in northern Ontario under very cold conditions and has survived baking in the TADD system as part of our trial. Although the system is only rated to IP67 it is actually physically embedded in the body of the trailer and therefore not subjected to the full power of a high pressure power wash during cleaning and has to date withstood that process. Further testing is underway to challenge this.

Many regions, such as Ontario, are requiring some form of GPS logistics system installed on all trucks over a certain size. These are designed to monitor and validate driver behaviour and provide information on the truck operational systems. Because they are monitored via GPS they can easily be integrated into centralized systems such as the Farm Health Guardian system. As logistics systems become increasingly the norm, many larger companies in the agricultural sector will require these. Ideally, they will be willing to share this data to help protect industry if disease is suspected.

One of the ways in which we were able to compare the accuracy of our trial GPS devices was to compare the data collected from the battery and wired trailer devices with the data collected from the vehicle internal GPS logistics system when one was available. By using API's available from the vehicle logistics system providers we were able to make meaningful comparisons between the data we were collecting from the pilot devices and the logistics systems permanently running in the trucks pulling the trailers. This way we could validate the accuracy of the data being collected from our trial devices.

Bluetooth Low Energy Devices

We tested three Bluetooth Low Energy (BLE) systems. BLE systems tested consisted of two components a Beacon (a sensor mounted on the vehicle), and a receiver (Gateway) installed at the property. When the beacon comes within range of the Gateway a signal is sent to a server via the internet or cell service.

The system time stamps the arrival of the vehicle. However, in a number of cases we found that the receiver range stated by the manufacturer was far greater than experienced during testing. For example, in one case the stated ranges were 250-300 meters. Our testing found reliable ranges of only around 25 meters. Setup the of the gateway/receiver on the property is relatively complex as Wi-Fi or reliable cell service is required and therefore placement is important. Any obstacles on the property interfere with the signal so clear line of sight is key. If all is working correctly this technology allows for tracking of devices within range of the gateway and provides notice that the device (vehicle) is in range of the receiver. It does not record the actual location of the Beacon.

LoRa Devices

We examined the emerging technology of Long-Range Local Area Network or LoRa LAN. As with BLE discussed above, receivers (gateways) are required on each property and the vehicles need to carry a beacon of some description that the receiver will connect with. LoRa can however deliver a much stronger signal over a much greater distance than BLE. LoRa can for example transmit to a radius of up to 15 kilometers. As a result, the LoRa system does present some interesting options for receiving vehicular data at, and transmitting that data from, properties through a single LoRa transmitter to a cloud server.

For example, a LoRa LAN can be set up which will require only one transmitter strategically located to receive transmissions from multiple farm-based receivers (Gateways) on surrounding properties. The farm-based receivers collect information from the beacons being carried by devices on vehicles visiting those properties. An ideal location for a LoRa LAN would be to have the transmitter located on top of the highest point in a region, for example an elevator, which would receive signal from surrounding properties. This reduces the data costs significantly as unlike BLE there is no need to have each farm-based gateway connected to the internet. The cost of installation and data charges is therefore significantly reduced. Note line of sight between Gateways and Transmitter is required however in relatively level (flat) regions such as in the Prairies in Canada, this is not problematic. Also one would need either a high density of farms belonging to a single entity or to have cooperation between neighbours to set up such a system.

Cellular options are available but are more costly. Receivers/Gateways should ideally be located outside of any building or placed in a window if they are in a steel building so that the signal isn't blocked. This is also true for BLE gateways.

The vehicle device is simple to install either externally on the vehicle in the case of trailers or carried inside the vehicle. Care should be taken not to mount the beacon where metal in the vehicle will block reception. Ideal mounting position is on the vehicle dashboard.

RFID devices

RFID devices were considered and researched at length.

The two most common types of RFID technologies are Active and Passive. Active RFID transponders are self-powered and are more expensive than Passive. Having power on board allows the active tag to have greater communication distance and usually larger memory capacity. The most common application for Active RFID is for highway tolls such as the Highway 407 in Toronto, ON, Canada.

The first is the familiar passive RFID which is commonly used in cattle ear tags. In this case the reader and the tag need to be in close proximity for the reader to connect with the tag (<15 metres). This is not practical for monitoring vehicles unless a specifically designed entry gate is provided at the farm entrance to bring the vehicle carrying the RFID tag and reader close together. The cost of building such an entrance is prohibitive for the majority of farm sites.

The ideal system would be a similar system to those found on toll roads such as the 407 in Ontario. These systems are medium range RFID and work at a distance between tag and reader of about 10 metres. These RFID systems require a static reader mounted somewhere within range of where the vehicles will be passing and an in vehicle 'active' (battery powered) RFID tag.

The cost of these systems is prohibitive from the mounting of the reader to the tags which cost anything from $20-$50 per tag, a cost that many vehicle operators will not want to bear.

The extra cost required to operate these systems is the cost of getting the data from the reader to the cloud system which requires some form of transmitter in the system. In order to try and address these cost issues we built a multipurpose RFID reader so that it could be used for more than simply tracking vehicles, but again the signal distance in the case of passive beacons and the cost of tags in the case of Active readers was found to be prohibitive. We do not recommend RFID for the Use case we are testing. To recap we are looking for low cost, simple systems that are easy to deploy and maintain. They m=need to be 'agriculture proof' and provide high levels of accuracy. Without these attributes a system for tracking and tracing trailers in a livestock and poultry working environment will not be successful.

Overall findings:

The more costly devices performed better (data accuracy, durability, etc.) than those that had a lower purchase price. For all devices, there must be a mechanism to link or integrate the technology to a system such as Farm Health Guardian.

The ideal device for the purposes of monitoring vehicle movements should have the following features:

All devices:

- Clear set up instructions and simple installation, with no requirement to be wired into the vehicle
- Operate on 4G LTE-m, ideally with 2G or 3G fall back for areas that do not have 4G or have limited connectivity
- Intuitive web portal by device manufacturer to access information easily on computer and tablet

For external products:

- Operating Temp: -40'C to +85'C

- IP Rating: IP69K (for dust and high pressure washing/water ingress) & IP67 (weatherproof and water resistant up to 1m submerged)

For battery operated devices:

- 3–5-year life span based on multiple GPS reads per day (multiple reads meaning on stops and starts, and every 5 minutes during motion for 8 hr per day, three days per week)
- A stop start option with a stop being recorded after no more than 5 minutes at rest
- Ideally rechargeable via solar or other means and / or have user replaceable batteries

Nice to have:

- Other sensors (light, temperature, etc.)
- Integration options and ability to share data with a system that will interpret and make it useful
- Comprehensive API documentation that clearly outlines integration and data sharing with other systems, for example a biosecurity system like Farm Health Guardian

Recommendations

Track and trace, or contact tracing, is shown through modeling and analysis to be a highly effective tool for controlling disease spread and for mitigating the negative impacts of control strategies. These control strategies include quarantining of premises, culling of animals, and financial losses from reduced production and delayed shipping due to movement restrictions.

Recommendations for industry and government:

- All livestock trailers and trailers that regularly frequent operations where livestock and poultry is housed or where such vehicles regularly visit premises such as feed mills, processing plants, truck wash bays etc. where cross contamination can occur should be tracked using sensor devices.
- Government support for the investment of track and trace sensors in livestock and poultry sector.

Recommendations for biosecurity:

- Number and frequency of farm visitors: Review the number and type of visitors to your farm operation/s. Understanding people and vehicle movements within a network is essential to prevent and control spread. Disease transmission occurs mainly through movement of animals, people & vehicles and Disease transmission risk increases with frequency of visits to a farm. Before investing in technology to monitor vehicle movements, decide whether you can reduce the number of vehicles entering your farm and the number of times they visit. For example, would larger feed storage reduce the number of visits your feed company makes to your property?
- Visitor logbooks: Invest the time in ensuring your visitor record books whether electronic and automated (best option) or otherwise are accurately filled out. Train your staff to insist on this because when there is a disease outbreak ". Contact tracing is the best intervention for controlling swine (all infectious) disease spread".
- Communicate: Switching to automated tracking of vehicles in and out of your properties will not be as hard for your suppliers if you explain to them why you're doing it and what you expect. For example, start requiring proof that live-haul vehicles have been thoroughly cleaned and disinfected before they come onto your property. A dedicated trailer tracking system is the only way to do this. Relying on verbal assurances is not enough.

Recommendations for sensor devices:

Tracking vehicles is really important but there are some steps you can take to optimize the value of the hardware you buy before doing so.

- Use case: Be sure you understand your use case when selecting sensors. We did not find a single sensor currently on the market covers all the needs of vehicle and trailer tracking in an agricultural environment.
- Battery Life: There is a trade-off between battery life and the degree to which you require position accuracy and timeliness of data. For epidemiological purposes, it is important to know when a vehicle enters and leaves farms and associated livestock premises (feed-mills etc.). We recommend you select systems with functionality that allows the user to adjust signal timing from the device to the central database, or alternatively has settings which only record vehicle stops and starts. Most companies will advertise that their devices have a multiyear (usually 3-5) battery life. This is based on minimal reporting/signals from the device usually once or twice every 24 hours. This kind of reporting is good for broadly understanding where a trailer has travelled or is parked, but not useful for tracking actual time of access and egress on properties in real time.
- C&D requirements: Any external sensor devices being used on livestock transport trailers that could potentially be subjected to high pressure washing must have the IP69K rating. This rating demonstrates that the device has been specifically tested for resistance to high pressure, high temperature spraying.
  Ensure that the sensors you select are resistant to the cleaning and sanitizing/disinfection agents you regularly use.
  If trailers are being exposed to Thermo-assisted Drying and Decontamination (TADD), the devices should be able to withstand high temperatures for reasonable lengths of time. Check what temperature your regular TADD bay is using before purchasing Sensors. We recommend that sensors being subjected to TADD should be able to withstand 85°C (185° F) for at least 15 minutes.
  Additional Temperature requirements for cold climates: As most battery powered GPS sensors used on trailers require a clear view of the sky it means their ideal location will be on the outside of the trailer. If your transport takes you into regions where winter temperatures go below -40°C (-40°F) it is recommended that you select sensors that are rated to be able to withstand at least that temperature.
  Note: Windchill will be a factor on a moving vehicle however, we were unable to find a battery powered device rated to operate below this temperature.
- Data Privacy: While this whitepaper only concerns itself with the use of devices to monitor the movement of vehicles (specifically trailers), the issue of data privacy cannot be ignored. Privacy is a key consideration when selecting any system that is reporting movements. Data being transferred from devices to the cloud are susceptible to 'man in the middle' attacks. The reasons are many and vary from company 'A' seeking information about company 'B's' regular routes, basically corporate espionage, to activists and particularly in the case of livestock and poultry trucking, welfare activists, intercepting location data and planning campaigns to disrupt transport in order to draw attention to their cause.
  To ensure that the data flowing from vehicle to cloud storage is secure, it must be encrypted. There are many systems that provide such encryption, but many do not. For example, in this project one

system was rejected simply on that basis. Suffice to say that the unencrypted systems are generally cheaper than the other systems and often come with no guarantees that the data being transferred will be encrypted, nor that the company providing the system will not use the information itself. It is our recommendation that only systems that encrypt data being transferred and the companies that sell them will attest to this claim should be used and that the companies agree not to use the data for financial gain.

This brings us to the last point which is the cost of data. Systems which report to a central data base have a cost of data to cover. Every jurisdiction will be different and each company will have its own preferred data supplier. It is worth checking the cost of the service before buying a system. For example, a cheaper system may bring with it high data fees. Some companies build data fees into their overall charge for the device. If you have vehicles travelling between jurisdictions e.g., USA and Canada it is important to ensure that the system will work in both jurisdictions and to understand if there will be roaming charges when the device moves out of its home jurisdiction. Our recommendation is to select a system that carries a universal SIM card so that it works in any jurisdiction anywhere in the world and the data fees remain the same regardless of where the transmission is originating.

The above only applies to devices that are directly connected to the internet. It does not apply to those devices which are based on a beacon and gateway system where the gateway is connected to the internet via a central router.

Making use of data: Most companies that manufacture and sell sensors provide a dashboard and various features to help you track and trace vehicles. However as with GPS logistics systems these features are vehicle rather than property centric and in order to make sense of the data from a disease management perspective a system needs to have specific mapping capabilities and attributes that are not usually available from off the shelf systems. It is important therefore that the company supplying the sensors will provide an Application Programming Interface (API) that will enable the movement data collected by the sensor to be transferred to a system designed to provide epidemiological information (such as the Farm Health Guardian system).

The following table summarizes the attributes of the various technologies tested during this project.

Device type	**Description**	**Best use case for track and trace in livestock and poultry trailers**	**Hardware Price and monthly fees** (Current as of 2021-22; range if applicable)
Small GPS – battery powered	Small lower end GPS devices, accuracy good but the battery-life/frequency of signal makes this device unsuitable for real-time reporting of position battery life severely compromised when set to anything other	Best suited for trailer that is not frequently and violently washed e.g. Horse trailer.	Hardware $100-120 Combined data and API fees CAD $13-$20 per month

	than the lowest frequency of signal to satellite. Very easy to install, readily available in Canada, serviced and maintained in Canada.		
GPS with solar	As per above but the added solar panel does make it a little better on battery life	Best suited for trailer that is not frequently and violently washed e.g. Horse trailer. Will withstand TADD at +75C and weather exposure as low as -50C. Generally only IP67 rated.	Hardware $120-150 Combined data and API fees CAD $13-$20 per month
Mid-range GPS – battery powered	Mid-range GPS devices, high accuracy, battery life severely compromised when set to anything other than the lowest frequency of signal to satellite. Very easy to install, shipped from US serviced and maintained in US. Service slow as the companies that sell these devices generally are dealing in volumes of hundreds or thousands and not less than 100 units.	Best suited for livestock hauling and other heavy goods trailers. Look for IP rating of 69 or above to ensure no water ingress during power washing. Will withstand TADD at +75C and weather exposure as low as -50C	More expensive so often sold on contract only. Look for hidden costs in these devices. Usually contracts run 1-3 years. Contracts range from $12 to $20 per month. API and data charges usually included
Higher range GPS – battery powered	Higher range robust devices. Excellent battery life as GPS positions are stored on the device and only released at intervals set by the user. These tend to have bigger battery with more powerful signal strength so can	Best suited for livestock hauling and other heavy goods trailers. Look for IP rating of 69 or above to ensure no water ingress during power washing. Will withstand TADD at +75C and weather	More expensive devices Often sold with upfront hardware fee ($250+ range) Plus a contract. Look for hidden costs in these devices.

	be fitted on truck chassis which can protect them from weather and water incursion and theft.	exposure as low as -50C	Usually minimum contract 3 years but can be as short as 1 year. Data costs range from $9 to $15 per month.
	OBDII devices - various makes. Easy to fit and 'splitters' available if you already use OBDII port for other purposes. All have excellent coverage - the price range and the size of the devices varies considerably but all appear to be reliable. Big drawback you do not get trailer coverage - excellent for delivert=y vehicles, tech vehicles etc.	For use in-vehicle only.	Generally contract only Fees $25-$50 per month - includes data and API fees. Monthly price varies with length of contract.
Tail light GPS - powered	Trailer tail light device - we only found one. It is easy to fit, robust, very accurate and no battery required. Fits most but not all N. American trailer models and no EU ones yet.	Best suited for livestock hauling and other heavy goods trailers. Look for IP rating of 69 or above to ensure no water ingress during power washing. Will withstand TADD at +75C and weather exposure as low as -50C	Hardware $250-300 Combined data and API fees $13-$20 per month
Devices requiring hardware at the farm			
LoRaWAN (Long Range Wide Area network) , Bluetooth, Bluetooth Low Energy, RFID.	All these systems require a reader positioned indoor or outdoor at the property and a beacon (sensor) in the vehicle. The beacons are usually	Suitable for tracking all types of vehicles. No tracking outside of the range of the readers so these devices suit companies not	Hardware: Readers: CAD $130 - $800 Beacons: $9.50 - $40.00 Monthly API Fees:

	small and can be carried in-cab or fixed to the truck or trailer body making vehicle installation very simple. The readers on the other hand need to be specifically positioned with good line of sight to the vehicle, need to be connected to WIFI or cellular network and hardwired to the power supply. The readers vary in price with outdoor being the most expensive.	wishing to have other locations they visit recorded in the central system. Downside is you need someone with some level of technical skill to position and set up these correctly. Also, there may need to be some programming undertaken to ensure accurate entry and exit times are reported. We found promises of accuracy, reliability and simplicity far outweighed reality. Also look for systems that encrypt signals. There are a number of cheaper Chinese devices on the market which require a lot of programming skills and the data integrity (protection) is not guaranteed. The upside is that if the readers are connected to the system via WIFI then there are no data fees. Having said all this, for privacy and dependability, we think these devices will in future, have a lot to offer for livestock and poultry industry trailer tracking.	$1.50 – $4.00

Appendix A: Acknowledgements

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Appendix B: Photos of examples of types of devices tested

1. Battery powered devices

2. Wired OBDII devices

3. Bluetooth low energy devices and receiver/gateway

4. LoRa device and receiver/gateway