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IN-FOREST CONNECTIVITY
V2X RESOURCE ROAD MESSAGE SET AND USE CASES

PROJECT NUMBERS: 301013567 and 301014119

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Intelligent transportation system safety applications such as an approaching vehicle emergency warning, co-operative collision warning system, and co-operative adaptive cruise control, may have potential to improve road user safety on resource roads. This report documents a feasibility study of these safety applications under the operating environments and road conditions of resource roads. This report found that existing safety messages could be tailored to the needs of resource road operations. Two safety-related use cases (i.e., oncoming vehicle warning and one-lane bridge warning), and two non–safety-related use cases (i.e., platooning and teleoperation) are presented.

This report is part of V2X report series. Refer Technical Report no. 20 to know more about user interface for broadcasting V2V basic safety messages to drivers and Technical Report no. 55 for V2X coverage results.

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INTRODUCTION

Canada has more than one million kilometres of publicly owned road networks, approximately 60% of which are unpaved roads that are shared between industrial and public traffic (Statistic Canada, 2018). The maintained unpaved road networks, with an efficient and safe road transportation system, contribute to Canada's economic growth and support its competitiveness in the global economy. Connected vehicle technology makes transportation efficient and safer, and this supports the goal of Canada's Road Safety Strategy 2025 to make Canadian roads the safest in the world (CCTMA 2016). With recent advances in vehicle connectedness, governments in the U.S. and Canada plan to mandate this technology for all new commercial and private vehicles on the roads soon (Knapp, Bullock, & Stogios, 2020). Implementing this technology is expected to reduce traffic fatalities and injuries, delivering a savings of $53 to $71 billion per year and positive net benefits within 3 to 5 years. Some automotive manufacturers have already altered production lines to provide this technology as a standard option on all new vehicles starting in 2021.

Several intelligent transportation system safety applications would apply to resource road operations, such as:

- Approaching emergency vehicle warning (where an emergency vehicle warns nearby road users of its current location, direction of travel, and speed);
- Co-operative collision warning (where a vehicle warns nearby vehicles about its proximity to a lead vehicle using wireless communication and not relying on advanced driver-assistance systems sensors); and
- Co-operative adaptive cruise control that can be used in a resource roads application.

These safety applications are generally designed for urban environments, however, and the operating environments and road conditions of resource roads are very different than those of paved, divided roadways. Lower-volume resource roads are one and a half lane wide, undivided, gravel-surfaced industrial roadways with widenings (pull-outs[1]) built regularly along their length. In some cases, the road may be only one lane wide. Currently, industrial vehicles use very-high-frequency (VHF) radios to communicate their location and travel direction to nearby vehicles. Starting in 2016, the BC Ministry of Forests mandated a new, advanced radio communication protocol for forest service roads that featured a dedicated bank of resource road narrow-band radio channels, uniform calling protocols with limited flexibility for local customization, and standardized sign formats to facilitate location calling (BCFSC 2016). Development of the efficiency and performance of VHF radios, however, has not progressed much in recent years, and this technology still has limitations due to operator error, signal interference, poor maintenance, and signal loss under certain atmospheric or terrain conditions. A paradigm shift with the adoption of new vehicular communication technology is needed to create a significant improvement in safety and traffic efficiency performance.

[1] road widenings on one side of the road

Figure 1 illustrates the paradigm shift expected from the deployment of vehicle-to-everything (V2X) technology, which is a key enabler for autonomous driving. Integration of V2X technology with 5G networks and low-Earth orbit satellite technology will improve safety and efficiency performance considerably, particularly for automation and teleoperation applications on resource roads.

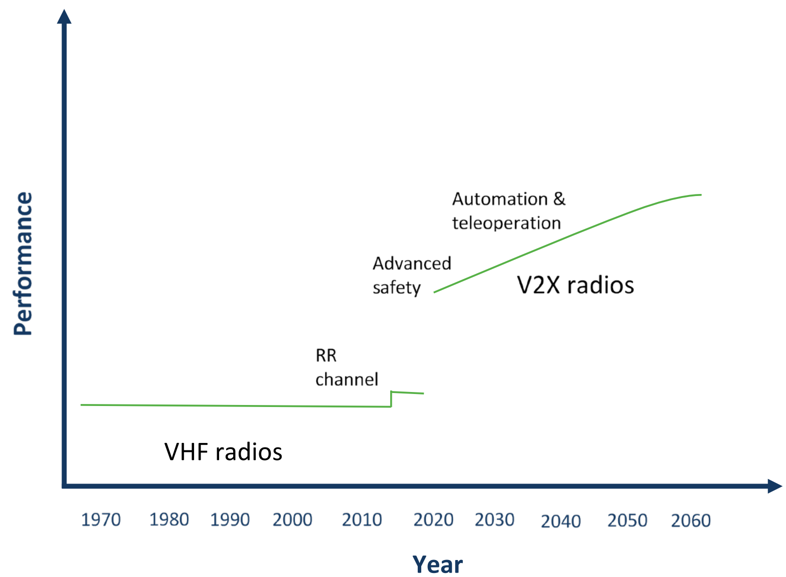

Figure 1. Paradigm shift timeline for improved safety and efficiency performance on resource roads. *(RR, resource road)*

With connected V2X technology, communications could be automated with high reliability and low latency. However, the message set developed for an urban environment must be adopted to resource road needs. In addition, use cases for resource roads must be defined so that V2X safety communication can be tailored for them.

OBJECTIVES

The objectives of this report are to:

1. Define the use cases for V2X technology on resource roads.
2. Tailor the current V2X message set to the requirements of resource road use cases.

RESOURCE ROAD USE CASES

Safety use cases

Some current V2X applications that were developed for urban environments could potentially be adapted to improve the safety of resource road operations. These applications include (National Academies of Sciences, Engineering, and Medicine [NASEM], 2017):

- Forward collision warning, which enables a vehicle to broadcast a self-generated emergency brake event to surrounding vehicles; this is especially useful in adverse weather events.
- Intersection movement warning, which warns a vehicle's driver when it is not safe to enter an intersection due to a high probability of collision with other vehicles at stop-sign-controlled and uncontrolled intersections.
- Emergency electrical brake light, which enables a vehicle to broadcast a self-generated emergency brake event to surrounding vehicles.
- Blind spot warning and lane change warning, which warn the driver of the host vehicle (HV) during a lane change attempt if the blind zone the HV intends to switch into is occupied or will soon be occupied by another vehicle (also called a remote vehicle [RV]) travelling in the same direction.
- Do-not-pass warning, which warns the driver of the HV during a passing manoeuvre attempt that a slower-moving vehicle, ahead and in the same lane, cannot be safely passed using a passing zone that is occupied by opposite-lane vehicles in the opposite direction of travel.

The SAE J2945 standard (SAE International [SAE], 2016) describes these applications and their on-board safety requirements. The forward collision warning application provides a warning to a driver about an oncoming vehicle so that the driver may slow down to pass or enter and wait in a pullout.

The following section describes two additional use cases for which V2X could bring safety and efficiency benefits to resource road operations.

Oncoming vehicle warning

Definition

An oncoming vehicle warning warns the driver about an oncoming vehicle on narrow sections of a resource road.

Description

Generally, loaded log trucks have the right-of-way on resource roads, and light vehicles and unloaded log trucks will pull over for loaded vehicles. In some cases, loaded log trucks may have to give the right-of-way to public vehicles without radios, vehicles carrying explosives, fuel trucks, loaded low-bed trucks carrying large equipment, or emergency medical services vehicles (ambulances).

If the road section is too narrow to pull to the side to allow a vehicle with the right-of-way to pass, the alternative is for the driver to pull off the road into a pullout and wait for the vehicle with the right-of-way to pass safely. Figure 2 illustrates an oncoming vehicle warning situation on a resource road. Pullouts are one-lane-wide widenings constructed on one side of an undivided road; they are normally 30 to 50 m in length and located every 300 to 1000 m (mainly on secondary resource roads). Additional pullouts may be located in higher-risk zones of the resource road (e.g., to either side of one-lane bridges, steep hills, and near curves where sight distance is limited). Pullouts are normally designed to accommodate one or two log trucks (or multiple light vehicles), depending on length. Consideration of traffic pulses and the presence of convoys may also affect pullout length and frequency.

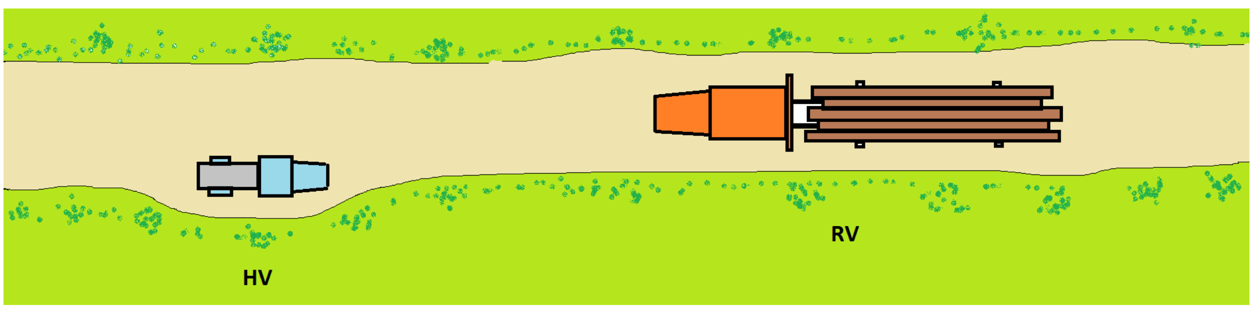

Figure 2. Situation for an oncoming vehicle warning.

Table 1 presents the recommended stopping sight distance at the design or operating speed that must be considered in this use case for estimating manoeuvre completion time.

Table 1. Stopping sight distance based on B.C. forest service road specifications (Ministry of Forests, Lands, Natural Resource Operations and Rural Development, 2019)

Design or operating speed (km/h)	20	30	40	50	60	70	80
Minimum stopping sight distance (m)	40	65	95	135	175	220	270
Minimum road width (m)	4	5–6	5–6	≥8	≥8	≥8	≥8

The environment and conditions for this use case are as follows:

- Target environment (environment where the specific use case applies): Resource roads and unpaved roads.
- Pre-conditions (conditions present before the V2X system is activated): Nearby vehicles are detected, and their message packets are authenticated (verified to be genuine).
- Triggering condition (condition that activates the V2X system): Oncoming are vehicles detected within the 2-km range.
- Post-conditions (conditions that prompt the V2X system to go into sleep mode): The two vehicles have met and passed each other safely.

Table 2 shows the requirements for an oncoming vehicle warning use case. These requirements and their values are from 5G Automotive Association standards (Fernandez et. al. 2019), some values of which were tailored to specific use cases. Positional accuracy, manoeuvre completion time, mobility, and relevance area are vehicle-related requirements, whereas availability, communication range, data rate, latency, reliability, and service data unit size are network-related requirements.

Table 2. Oncoming vehicle warning use case requirements

Parameter	Requirement value
Positional accuracy	5 m
Manoeuvre completion time	100 s
Mobility	0 to 100 km/h
Relevance area	2 km to oncoming vehicle on undivided road
Network availability	Vehicle-to-vehicle (V2V) communication 99.99%
Communication range	≥1 km
Data rate	1 to 28 Mbps
Latency[a]	100 ms
Reliability	99.99%
Service data unit size	69 to 168 bytes
Power	Low power consumption (vehicle-based)
Security	Privacy: High Confidentiality: Low Data integrity: High Network authentication: High

[a] Length of time of transmission of data packet from the transmitter to the receiver.

In the context of resource road operations, there would be a need to identify the vehicle type (e.g., log, chip, biomass, or rock trucks; industrial or public light vehicles; equipment transport trucks [low-bed trucks or float trucks]; and other industrial traffic, such as fuel, service, and explosives trucks). Loading condition (loaded versus unloaded) would be another important attribute. Finally, some consideration should be paid to the needs of heavy and light industrial and public vehicles trying to pass one another while travelling in a convoy.

Use cases from an urban environment include the approaching emergency vehicle warning and the wrong-way driver warning. If found to be of interest to resource road managers, these should be investigated and adapted to resource roads.

Scenario

Resource road networks in Canada typically feature several classes of roads, ranging from very-low-volume, slow-speed, narrow harvest area (in-block) roads to low-volume, high-speed, two-lane-wide mainline roads. Safety issues on mainline roads are usually related to unexpectedly meeting wide or long heavy trucks; unexpectedly encountering wildlife or road hazards; slippery road conditions; speeding vehicles and unsafe passing (especially by public vehicles with no radios); reduced sight distance caused by dusty conditions, curves, or encroaching (unmanaged) roadside vegetation; reduced road width caused by soft shoulders, grader berms, or snow banks; and rough road conditions caused by lack of surface maintenance or worn-out roads. The three typical classes of resource roads are described as follows:

- **Mainline roads** (wide resource roads with more traffic than the other two types of resource roads):
    - Generally, two undivided lanes with additional widening through curves.
    - Road running surface width on straight sections is 8 to 12 m.
    - Gentle horizontal curves of 100-m radius or more, with road widths of 8 to 10 m.
    - Maximum travel speeds are no more than 90 km/h (25 m/s); therefore, the relative approach speed (differential speed) between two approaching vehicles is no more than 50 m/s. In some cases, the maximum travel speed may be exceeded (e.g., trucks temporarily speeding as they approach a steep hill to climb it).
    - Loaded heavy trucks generally have the right-of-way on resource roads; therefore, it is important to identity them.
    - Vehicles may slow down when passing, especially if visibility is reduced (snow, dust, fog, darkness, etc.).
    - Drivers need a minimum 20 second warning of an oncoming vehicle to allow time to slow down and safely move well over to their own side of the road. A 20 second buffer when two approaching vehicles are both travelling at 90 km/h corresponds to being warned when those vehicles are separated by 1 km (i.e., the trucks would meet in 500 m).

- **Secondary roads** (roads connecting mainline roads to numerous in-block roads):
    - Running surface width of 1.5 lanes wide (no more than 6 to 8 m wide).
    - Medium horizontal curves of 35 to 65 m radius.
    - Maximum travel speeds of 60 km/h (16.6 m/s); therefore, the maximum relative approach speed between two approaching vehicles is 33.3 m/s.
    - Stopping sight distance of 80 to 165 m.
    - Vehicles slow down and pull to the road shoulder to pass each other or, if necessary, seek a pullout to yield the right-of-way to loaded trucks. If the distance to the next pullout is greater than can be safely travelled before meeting an oncoming loaded truck (e.g., 80–100 m, or 3 truck lengths away), then the driver should wait at the closer pullout.

- **In-block roads** (tertiary roads; low-standard roads in a harvest area):
    - One- to 1.5-lane road (4.5 to 6 m wide).
    - Winding alignment with tight horizontal curves (≥25 m radius).
    - Maximum travel speed of 40 km/h (11.1 m/s); therefore, a relative speed of no more than 22.2 m/s.
    - Tight curves and narrow road surfaces; V2X technology would provide a maximum benefit on these types of roads.

Table 3 summarizes the estimated pullout spacing based on road type according to past studies (Kurowski 2018, Mosslemi, Bradley and Shetty 2014, Shetty and Bradley 2013); however, further studies must be conducted to have a better inventory of the number of pullouts, spacing, and pullout features for better planning of the use of connected and automated vehicles on resource roads.

Table 3. Pullout spacing based on road type

	Mainline	Active secondary	Active in-block
Flow (vehicles per day)	100–120	40–100	20–40
Pullout spacing (number per kilometre)	Up to 3	Up to 3	0
Road running surface width (m)	≥8	5–7	4.5–6

One-lane bridge warning

Definition

A one-lane bridge warning cautions a driver of the presence of an upcoming one-lane bridge and an oncoming vehicle.

Description

Most bridges on B.C. resource roads are one-lane wide (i.e., 4.3- to 4.9-m wide decks) and have a single span 3 to 36 m long. Resource roads are often narrowed to one lane wide in the bridge approach stretches to force road users to align their vehicles with the centre of the single lane before driving onto the bridge deck. Thus, the actual length of resource road that is narrowed at crossings can be considerably longer than the length of the bridge (Figure 3). Pullouts are also a common feature of resource roads near stream crossings. Pullouts allow one vehicle to pull off the road and stop to give the right-of-way to an oncoming vehicle. Typically, the right-of-way is given to loaded log-hauling trucks because they are less manoeuvrable and harder to stop and start than unloaded log trucks and light vehicles. Occasionally, pullouts at bridges are used for parking to inspect the bridge. If enough warning is given to vehicles to reduce speed before reaching the bridge, the traffic flow will be smoother at this bottleneck.

Regardless of whether there is an approaching vehicle, every vehicle crossing a one-lane bridge should align with the road centreline and reduce speed because there is an increased risk of collision on the bridge due to reduced sight distance, reduced room to manoeuvre, risk of colliding with bridge rails and curbs, and risk of loss of traction in icy deck conditions. Figure 3 illustrates this use case in which an HV detects a one-lane bridge transmitter (i.e., a roadside unit [RSU]) and an oncoming vehicle that has the right-of-way (RV) and warns the HV driver to pull into the next available pullout and wait until the way is clear. The occupancy of the pullout may also be considered if the RSU is installed at some key pullouts.

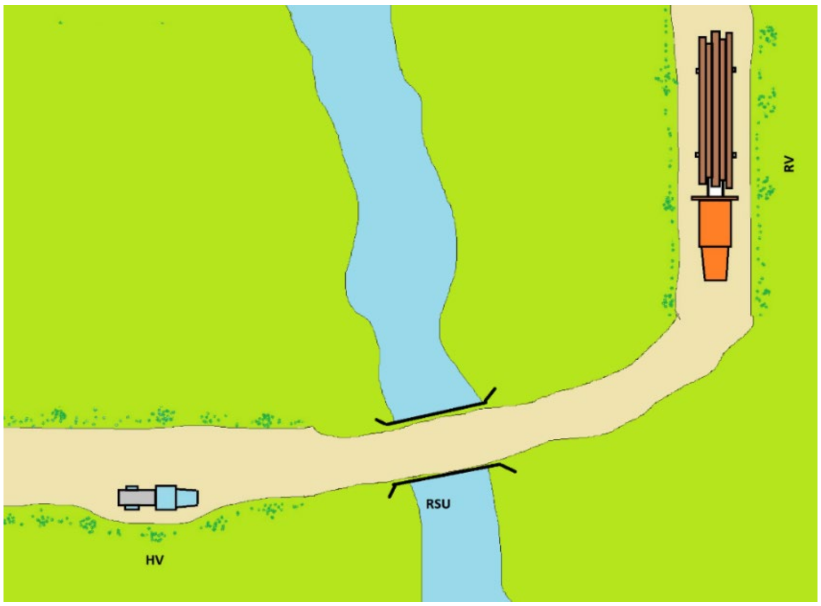

Figure 3. One-lane bridge warning.

The environment and conditions for this use case are as follows:

- Target environment: Resource roads and unpaved roads.
- Pre-conditions: Vehicles are in the vicinity of a one-lane bridge and the vehicles are authenticated.
- Triggering condition: Vehicle approaches the one-lane bridge.
- Post-conditions: HV pulled over and stopped, and the oncoming vehicle with the right-of-way crosses the bridge and passes the stopped HV.

Table 4 summarizes the use case requirements for a one-lane bridge warning system.

Table 4. Use case requirements for a one-lane bridge warning system

Parameter	Requirement value
Positional accuracy	5 m
Manoeuvre completion time	100 s
Mobility	0 to 70 km/h
Relevance area	2 km to oncoming vehicle on undivided road
Network availability	V2V 99%, vehicle-to-infrastructure (V2I) 95%
Communication range	≥1 km
Data rate	1.28 Mbps
Latency	1 s
Reliability	99.99%
Service data unit size	168 bytes
Power	RSU units must be powered with an alternative power source 99% of the time. The unit must ping.
Security	Privacy: High Confidentiality: Low Data integrity: High Network authentication: High

A similar use case in or near urban environments would be an approaching emergency vehicle warning.

Non-safety use cases

ABI Research predicts that non–safety-related V2X applications will grow to be 30% of all V2X applications by 2027 (ABI Research 2013). In December 2019, the Federal Communications Commission proposed the lower 45 MHz (5.85–5.895 GHz) in the 5.9 GHz band for unlicensed use. Therefore, this band could be used for non-safety applications in forestry, such as data transfer applications for electronic load tickets, electronic scaling, electronic hours of service data transfer applications, and others. Safety applications are usually broadcast continuously; however, non-safety use cases are not and, instead, would be event-based.

The environment and conditions for this use case are as follows:

- Target environment: Resource roads, in-block roads, government and mill yard weigh scales.
- Pre-conditions: The connection between machines, vehicles, or RSUs is established and authenticated.
- Triggering condition: When the vehicle is in the vicinity when synchronization is requested by the on-board unit (OBU) or RSU.
- Post-conditions: Requested data is received successfully.

Table 5 summarizes the requirements of this non-safety use case.

Table 5. Use case requirements for data transfer

Parameter	Requirement value
Positional accuracy	5 m
Manoeuvre completion time	100 s
Mobility	0 to 30 km/h
Relevance area	Around 1 km within the vicinity of a machine or truck
Network availability	V2I 99%, vehicle-to-machine 99%
Communication range	≥1 km
Data rate	5 Mbps downlink, 1 Mbps uplink
Latency	500 ms
Reliability	99.99%
Service data unit size	Depends on the type of application and the type of data transmitted
Power	Low power consumption (vehicle- and machine-based) for OBU and uninterrupted power for RSU
Security	Privacy: High Confidentiality: Low Data integrity: High Network authentication: High

Platooning

Platooning of heavy wood-fibre hauling trucks is the subject of current research and may become operational in the next 5 to 10 years. V2V communication technology used on platoon test trucks is dedicated short-range communication–based technology and is designed for spacing commonly encountered on highways; however, the spacing between platooning vehicles will be greater on certain occasions, such as while using pullouts, one-lane bridges, etc. Therefore, planning of engagement and disengagement of the platoon convoy must be taken into consideration. In addition, the passing of platoon convoys by other road users on resource roads would need additional considerations. The data rate for this technology is 3 to 65 Mbps or more, depending on the quantity of sensor data transferred; however, future requirements of platooning will be for data rates higher than 27 Mbps. Table 6 illustrates the requirements of the platooning use case.

Table 6. Use case requirements for vehicle platooning

Parameter	Requirement value
Positional accuracy	5 cm
Manoeuvre completion time	On disengagement
Mobility	0 to 100 km/h
Relevance area	2 km to oncoming vehicle on undivided road
Takeover time[a]	10 s
Network availability	V2V 99.99%, vehicle-to-network (V2N) 95%
Communication range	≥1 km
Data rate	Up to 65 Mbps or more dependant on sensor data type and transmission rate
Latency	10 to 25 ms
Reliability	99.999%
Service data unit size	6500 bytes
Power	Low power consumption (vehicle-based)
Security	Privacy: High Confidentiality: Low Data integrity: High Network authentication: High

[a] Maximum value that determines an upper limit when the automation takeover of the vehicle must have been completed (Fernandez et al., 2019).

Teleoperation

Recent applications investigated in the Forestry 4.0 initiative[2] have included the remote operation of automated harvesting machines and wood-fibre hauling trucks, with control of steering, braking, and throttle remotely via wireless communication. Current technology limitations require that teleoperation be conducted from a relatively close proximity to where the forestry machine or haul truck is operating. With the advent of low-Earth orbit satellite and 5G technology, however, the potential of operating machines or vehicles from far away will soon become a reality using unified connectivity. The local data transfer between vehicles could be done using V2V technology. Knowing the surrounding environment, such as traffic density and road characteristics, through V2V and V2I will be key for teleoperation of autonomous equipment and vehicles in the forest.

Figure 4 illustrates the potential network routing needed to create reliable, long-range connectivity for teleoperation. This network routing is conceptual connectivity using LTE-based technology in a forest operation scenario that can use the LTE core network, cell boosters, and local LTE networks for V2N. Cellular-based V2X (CV2X) devices can communicate directly outside cellular coverage using the LTE PC5 interface (i.e., without any network support). The CV2X PC5 interface supports the low latency required for V2V safety applications (Molina-Masegosa & Gozalvez, 2017). No SIM cards are required, and CV2X is considered a viable alternative to 5.9 GHz dedicated short-range communications to meet and exceed V2V

[2] Forestry 4.0 Initiative aims to bring the Canadian forest value chain to operate within the parameters of the Industry 4.0 standard of cyber-system connectivity and on-demand production.

requirements (Hu et al., 2017). CV2X has two complementary communication modes for maintaining connectivity.

One is direct, using the PC5 interface, which has a short range (>500 m) and operates in the intelligent transportation system 5.9 GHz reserved spectrum; the other mode uses the licensed spectrum of local networks via the LTE Uu interface (current cellular devices use this interface), so it has a range of more than 1 km. Since FPInnovations is working on a local LTE network to expand coverage in forestry operating areas, this LTE-based technology is of special interest because of its potential to support FPInnovations' current connectivity initiatives. The Uu interface and LTE sidelink V2V could be used for out-of-coverage communication through the PC5 interface. Some modifications might be required for complete connectivity using this technology.

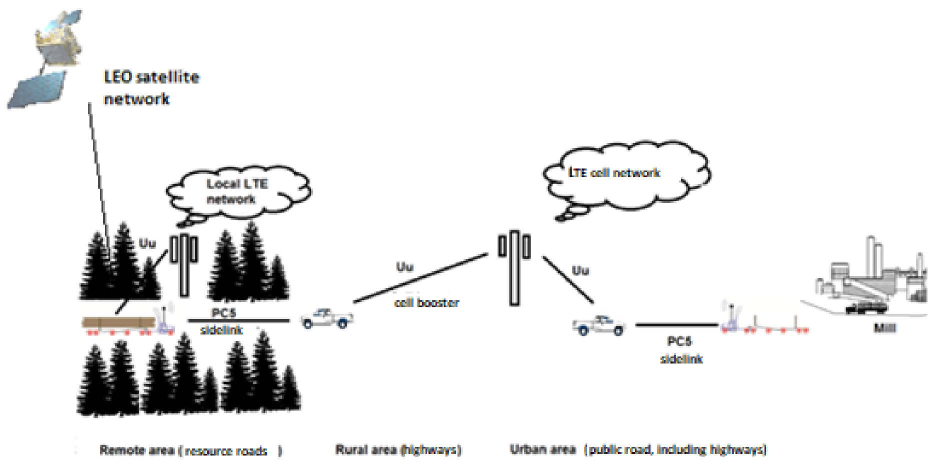

Figure 4. V2X network in a forest operations scenario. *(LEO, low-Earth orbit)*

The environment and conditions for this use case are as follows:

- Target environment: Resource roads, unpaved and paved roads (from source to destination and return).
- Pre-conditions: Vehicle is connected and authenticated.
- Triggering condition: Authorized communication to the vehicle is established.
- Post-conditions: The vehicle has finished travelling the route.

Table 7 depicts the requirements for teleoperation in forest operations.

Table 7. Use case requirements for teleoperation of forestry equipment

Parameter	Requirement value
Localization	50 cm
Manoeuvre completion time	Not applicable
Mobility	0 to 80 km/h
Relevance area	Vehicle route
Network availability	V2N 99.99%; V2I and V2V 95%
Communication range	Several kilometres
Data rate	6.4 to 20 Mbps
Latency	5 to 30 ms
Reliability	99.999%
Service data unit size	16 000 to 41 700 bytes per frame
Power	Low power consumption (vehicle-based)
Security	Privacy: High Confidentiality: High Integrity: High Authentication: High

V2V SAFETY MESSAGE

Basic safety messages (BSMs) are a key part of V2V communication and can be used in multiple V2X applications. BSMs are used to exchange safety-related information between OBUs of vehicles that can then be assessed for potential safety threats caused by nearby vehicles. The SAE J2735 standard (SAE, 2016) defines the formatting, structure, data frames (collection of elements), and data elements of BSMs used in V2V and V2I applications. A BSM contains 17 messages (collection of data frames and data elements), 156 data frames (collection of data elements), 230 data elements (primitive objects), and 58 external data element definition references. Table 8 summarizes the standard contents of an SAE BSM. All of the data elements in part 1 of an SAE BSM are mandatory and are broadcast 10 times per second; part 2 of the BSM may contain any number of optional vehicle-rated objects that are broadcast less frequently.

Table 8. SAE BSM data elements

Basic safety message	
	Element
Part 1	
Message type	
Message count	
Vehicle temp ID	
Time stamp	
Latitude	
Longitude	
Elevation	
Positional accuracy	
Transmission and speed heading	Transmission state, speed
Steering wheel angle	
Acceleration (3-axis)	
Brake status (data frame)	Anti-lock brake status, stability control status, traction control status, brake-applied status
Vehicle size (data frame)	Vehicle width, vehicle length
Part 2 (optional)	
Event flags	Anti-lock brake–activated, electronic stability control–activated, hard braking, hazard lights etc.
Path history	
Path prediction	
Radio Technical Commission for Maritime Services package	
Other vehicle data	

Key information about vehicles that use resource roads are vehicle type; direction of travel (heading); load type (loaded or unloaded); road distance if possible; number of vehicles in convoy (if applicable); and number of oversize vehicles, speeding vehicles, and vehicles with brake failures. The V2V message set seems to be flexible enough to incorporate this information except for the number of vehicles in a convoy, which needs to be investigated further. The common safety request message set could be used to acquire specific information in conjunction with BSMs. Incorporating a V2V message set in operational use cases would help identify any information gaps that must be incorporated for resource road use.

V2I SAFETY MESSAGE

In the case of message sets for use by infrastructure on resource roads, an RSU located at a one-lane bridge or pullout could be used to detect nearby vehicles and their status, heading, and type using a probe vehicle data message. The RSU would broadcast the message using probe data management. Table 9 summarizes the V2I message type, its purpose, and its applicability to resource road operations. This message type could also be tailored to resource road needs; however, these should be verified with a pilot trial(s).

Table 9. V2I message type

Message type	Purpose	Applicability
Roadside alert	RSU sends alert of a hazardous condition to passing vehicles	One-lane bridge (oncoming traffic), presence of a grader
Map data	RSU sends map-related data to passing vehicles	One-lane bridge (location and length of bridge), pullout (number of occupants, available space)
Probe vehicle data	Vehicle's OBU reports the vehicle status over a section of road	Slippery road, road roughness, rollover threshold application
Probe data management	RSU instructs vehicles to adjust threshold or transmission strategy, which is transmitted based on time and distance	One-lane bridge
Traveller information	RSU sends advisory and road sign type information to passing vehicles	Slippery road, road roughness, rollover threshold application

SUMMARY

Based on the literature review and preliminary assessment, the current SAE J2735 (SAE, 2016) data dictionary allows customization; therefore, the information related to resource road use cases could be tailored to meet the needs of resource road operations. Before being included in the data dictionary, however, V2X applications for the resource road use cases discussed in this report should be piloted in actual operations to assess their feasibility and identify knowledge gaps. Five potential use cases were discussed in this report; other use cases may also hold potential but should be pursued only after experience is gained with the successful demonstration of some of these initial use cases for resource roads.

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