

March 2026

Cellular Vehicle-to-Everything (C-V2X)

The Standards Shaping Connected Mobility

Recent developments curated and summarized
SEPs (Standard Essential Patents) and Industry news


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Preface



Cellular Vehicle-to-Everything (C-V2X) is a communication technology that lets vehicles share information with their surroundings in real time. C-V2X provides one unified solution for V2V (vehicle-to-vehicle), V2I (vehicle-to-infrastructure), V2P (vehicle-to pedestrian), and V2N (vehicle-to-network) by leveraging existing cellular network infrastructure. It improves road safety, reduces traffic congestion, and supports the transition toward connected and autonomous driving. C-V2X is developed and maintained by 3GPP, the global organization that creates mobile communication standards.

This monthly report highlights key developments in C-V2X standards, industry updates, and newly declared SEPs (standard essential patents). It is intended for engineers, researchers, technology leaders, IP (Intellectual Property) teams, and mobility professionals looking for a clear and simple overview of monthly C-V2X progress.

Key Insights

- ❑ Global filing activity across major automotive and telecom markets (US, China, Europe), supported by strong PCT coverage, shows that companies are building wide IP coverage for their C-V2X innovations. This approach signals worldwide usage of patent portfolios for future licensing and commercialization opportunities.
- ❑ To achieve safety-critical functions like collision avoidance and coordinated driving, 5G C-V2X requires stronger sidelink control and more reliable physical-layer performance. This is reflected in the high SEP (Standard Essential Patent) concentration around Technical Specifications TS 38.331 (Radio Resource Control) and TS 38.211 (physical channels and modulation), which enables these technical improvements.
- ❑ Huawei leads the SEP landscape by a wide margin and is heavily focused on TS 38.331 and TS 38.211, two core enablers for next-generation C-V2X, giving it potential licensing leverage as the ecosystem will continue to grow. In contrast, other major assignees maintain broader TS portfolios that cover a wider range of C-V2X technologies.
- ❑ Recent demonstrations and deployments in the U.S. show that C-V2X is moving from pilot phase to real commercial rollout, with proven interoperability across tolling, safety, and road-side systems. This validation, combined with deployments like Indra's smart express lanes, strengthens the case for connected-infrastructure investment. Together, they show that C-V2X is now mature, monetizable, and ready for faster adoption.
- ❑ LG's new module cuts hardware and wiring needs, making car connectivity easier and more cost-efficient for automakers. Its multi-signal support (5G, V2X, GPS, satellite) positions LG as a top-tier supplier for next-generation connected platforms.





The image depicts a multi-lane road lined with lush green trees. Several vehicles, including a dark SUV in the foreground and a white SUV further ahead, are shown. Above the vehicles, blue Wi-Fi symbols and glowing arcs represent wireless communication links between the cars. The road surface features blue directional arrows. The overall scene is set during the day with soft lighting.

C-V2X SEP Landscape

C-V2X

C-V2X (Cellular Vehicle-to-Everything) is a technology that lets vehicles share information with other vehicles, pedestrians, and roadside systems in real time. It helps prevent accidents, reduces traffic jams, supports efficient driving, and prepares the way for connected and autonomous vehicles.

C-V2X is standardized by 3GPP, the global organization that develops mobile communication standards for 4G, 5G and future technologies. 3GPP's work is carried out through three groups: **(1). RAN (Radio Access Network), (2). SA (System and Services), and (3). CT (Core Network and Terminals)**. These groups produce the Technical Specifications (TS) that define how C-V2X operates across different layers.

Which technologies does C-V2X include?

C-V2X evolves through major 3GPP releases:

- **4G LTE-V2X** (Release 14/15, 2017-2018): Initial version of C-V2X
- **5G New Radio (NR) -V2X** (Release 16/17/18, 2020-2024): Enhanced reliability, lower latency
- **5G-Advanced NR V2X** (Release 19, 2025): Latest phase with ongoing improvements

3GPP Release 19 continues to strengthen 5G-V2X with enhancements in sidelink communication, network efficiency, and system-level improvements to support advanced cooperative driving.

5G-Advanced NR V2X Sidelink

(The TS 38 series was introduced in Release 15 and has progressively evolved through Release 19.)

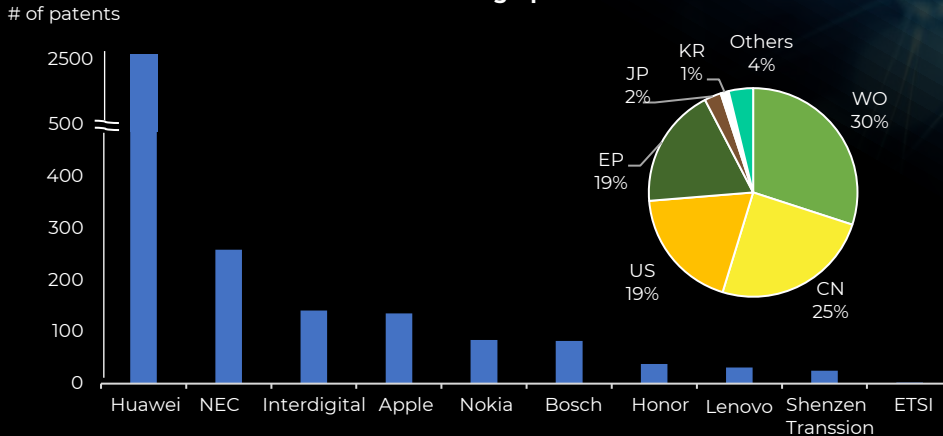
- TS 38.211: NR sidelink physical channels & modulation
- TS 38.212: Multiplexing and channel coding for sidelink
- TS 38.213: Physical layer (PHY) procedures for control
- TS 38.214: Physical layer (PHY) procedures for data
- TS 38.321: Medium Access Control (MAC) protocol specification
- TS 38.331: Radio Resource Control (RRC); Protocol specification
- TS 38.300: Overall NR/NG-RAN with sidelink architecture

5G-Advanced NR V2X Architecture (Service & System Layer)

(The TS 22 series began in Release 14, while TS 23 started in Release 16 and evolved through Release 19.)

- TS 23.287: Architecture enhancements for 5G System (5GS) to support Vehicle-to-Everything (V2X) services
- TS 22.186: 5G; Service requirements for enhanced V2X scenarios
- TS 22.185: LTE; Service requirements for V2X services

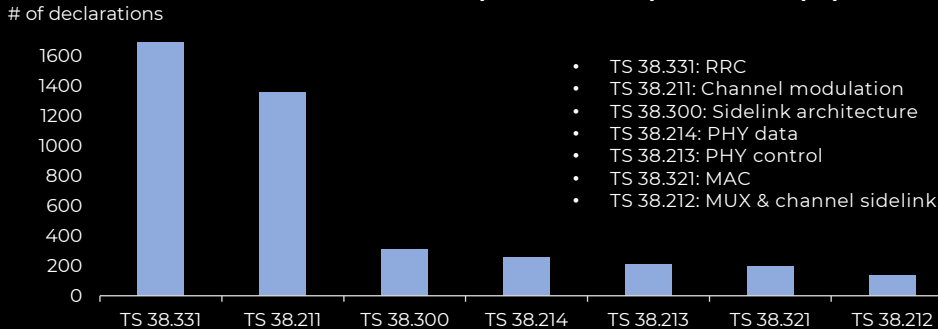
Top Assignees: Monthly patent activity related to C-V2X standard and Geographic distribution



As per February 2026 data

- Huawei leads the declaration landscape by a wide margin, but its activity is concentrated mainly on top two TS (38.211 & 38.331). However, other companies such as NEC, Interdigital, Apple and Nokia have a more diverse portfolio across all TS.
- NEC focuses on core technology patents in sidelink architecture (TS 38.300), while InterDigital builds strength in PHY-control procedures (TS 38.213) that shapes reliability, latency, and link performance.
- The global filing pattern shows a deliberate IP protection strategy, starting with broad PCT coverage, followed by strong presence in all major markets such as US, China and Europe, where V2X technologies are expected to scale.
- With TS 38.331 and TS 38.211 accounting for most sidelink SEPs largely driven by Huawei, the focus is clearly on strengthening RRC control and physical-layer modulation, the foundation of NR-V2X reliability.

Number of declarations per Technical Specifications (TS)





PATENT

The editor's shortlist

Declared Patents Of The Month



SEPs of the month

Declared in February 2026

Sampled and summarized by our analyst based on Assignee and Technical Specification (TS)

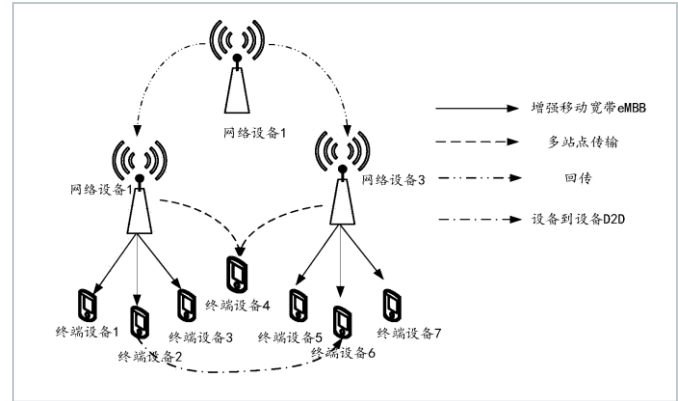
- [WO2023124890A1](#) - Modulation method, demodulation method and related apparatus
Assignee: Huawei Technology Co Ltd
- [WO2023126010A1](#) - Data transmission method and apparatus
Assignee: Huawei Technology Co Ltd
- [WO2025000530A1](#) - Carrier aggregation in sidelink communication
Assignee: NEC Corp
- [US2025344090A1](#) - RI/CQI prediction for multiple predicted CSI
Assignee: Interdigital Patent Holding Inc
- [WO2025174725A1](#) - Methods for collision avoidance for ambient IoT
Assignee: Apple Inc
- [WO2026022613A1](#) - Uplink, downlink and joint uplink-downlink radio link failure prediction
Assignee: Nokia Technology Oy
- [US2024053493A1](#) - Method and apparatus for a terminal device
Assignee: Robert Bosch GMBH
- [CN121151991A](#) - Satellite communication processing method and related device
Assignee: Honor Terminal Co Ltd
- [WO2025163525A1](#) - Machine learning at a wireless device
Assignee: Lenovo Singapore Pte Ltd
- [CN121194244A](#) - Processing method, communication device and storage medium
Assignee: Shenzhen Transsion Holding Co Ltd



◀ WO2023124890A1

Modulation method, demodulation method and related apparatus

Declared in TS 38.211 within the C-V2X standard.



Company name Huawei Technology Co Ltd

Inventors Shi Meng,
Zou Peng,
Zhang Jiayin

Priority date 27 Dec 2021

Publication date 06 Jul 2023

The patent describes a way to simplify probabilistic constellation shaping, a technique that assigns different probabilities to QAM symbols so lower-energy symbols (which require less power to transmit) are used more often. Instead of handling the in-phase (I) and quadrature (Q) parts (two signal waves at right angles that work together to carry data in a Quadrature Amplitude Modulation (QAM) signal) separately, the device creates one combined symbol stream that represents both components. This unified stream uses symbol types whose probabilities and amplitudes match the full QAM constellation, allowing flexible shaping. The device maps this stream into bits, combines it with another bitstream to form check bits, and creates QAM symbols by pairing amplitudes with sign bits. It can also use interleaving, which rearranges bits before transmission to improve error correction.

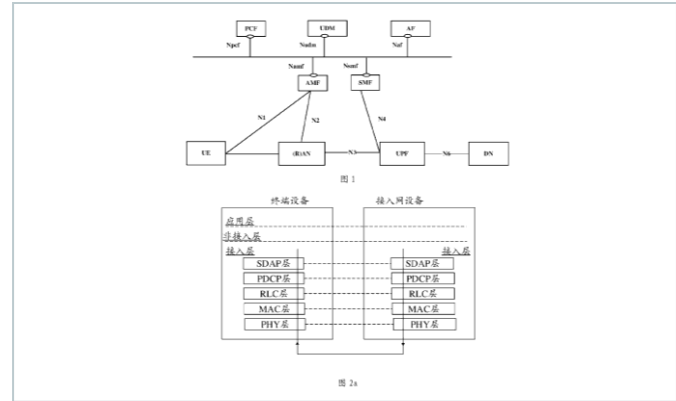


WO2023126010A1

Data transmission method and apparatus

Declared in TS 38.331 within the C-V2X standard.

Company name	Huawei Technology Co Ltd
Inventors	Fan Qiang
Priority date	31 Dec 2021
Publication date	06 Jul 2023



The patent helps a terminal device detect uplink packet loss more reliably for data that is not regularly sent in Industrial Internet of Things systems by starting a timer each time it sends a packet and waiting for the network to confirm that the packet was received. If the network sends feedback or a retransmission command before the timer ends, the timer stops, but if the timer reaches zero with no response, the device tells the network that the packet was lost. This early warning prevents long stretches of unnoticed packet loss that could cause timeouts and interruptions in services that need very high reliability. Once the network receives this warning, it can change how it sends or schedules data to fix the issue. The method can also activate Radio Link Control functions for PDCP replication, which sends a duplicate copy of the same packet to improve the chance of successful reception.

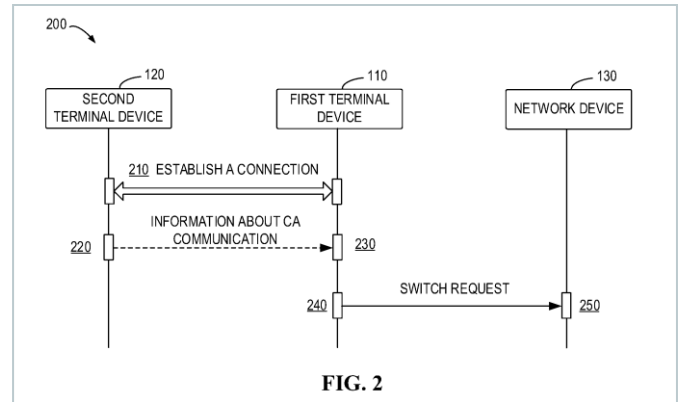




◀ **WO2025000530A1**

Carrier aggregation in sidelink communication

Declared in TS 23.287, TS 38.300, and TS 38.331 within the C-V2X standard.



The patent shows how two terminals using sidelink communication, such as in V2X, can use Carrier Aggregation (CA) to improve performance while still working with terminals that do not support CA. When two CA-capable terminals connect, it can ask the network to switch to a sidelink mode that supports CA, and the terminals share their CA capability information to make this change. If the CA configuration cannot be provided, the terminal can fall back to non-CA operation. The transmitting terminal also checks whether Packet Data Convergence Protocol (PDCP) duplication is active and sends the correct duplication status so that receiving terminals process the packets properly. For mixed cases where not all terminals support CA, the compatibility information is used to decide which carrier carries the main packet and which carries the duplicated packet, ensuring all terminals can receive the data correctly.



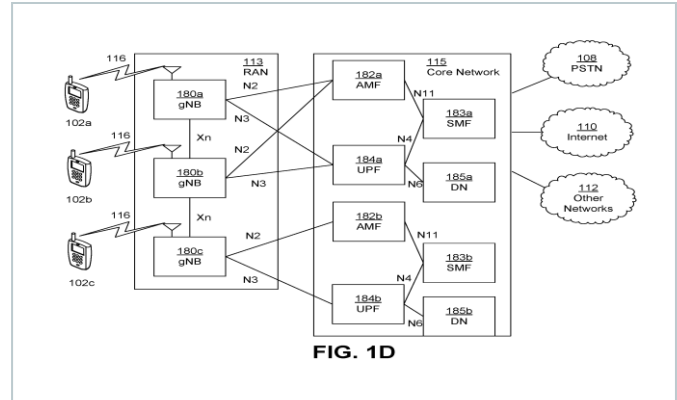
Company name	NEC Corp
Inventors	Miao Zhaobang, Wang Gang
Priority date	30 Jun 2023
Publication date	02 Jan 2025



◀ US2025344090A1

RI/CQI prediction for multiple predicted CSI

Declared in TS 38.213, TS 38.214, and TS 38.331 within the C-V2X standard.



The patent explains how a Wireless Transmit Receive Unit (WTRU) can better predict future Channel State Information (CSI) and quality metrics like Rank Indicator (RI), and Channel Quality Indicator (CQI), which are hard to estimate because interference often changes unexpectedly due to nearby cells or physical blockages. The WTRU receives configuration information, which includes historical Interference data, interference scaling factors, and indicators of possible future blockages. Using this information, the WTRU predicts future CSI values and calculates quality metrics for upcoming time periods. It may also use AI or ML models that take inputs such as predicted CSI, SINR estimates, interference levels, device movement, or blockage probabilities to improve accuracy. The WTRU can compress several RI or CQI values using adaptive compression types and then sends the predicted metric to the network.



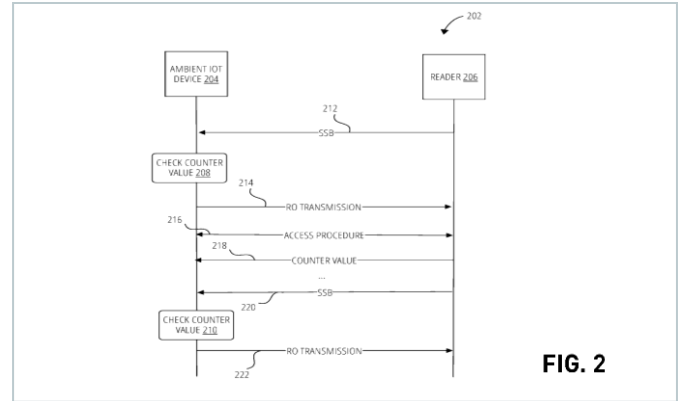


◀ WO2025174725A1

Methods for collision avoidance for ambient IoT

Declared in TS 38.212, TS 38.213, and TS 38.214 within the C-V2X standard.

Company name	Apple Inc
Inventors	Bhamri Ankit, Zhang Dawei, Zeng Wei, Ye Sigen, Sun Haitong, Bettancourt Ortega Rolando E, Yao Chunhai
Priority date	15 Feb 2024
Publication date	21 Aug 2025



The patent explains how ambient IoT devices can avoid interfering with each other when they try to access a wireless network. These low-power devices cannot stay synchronized and often try to connect at once, which causes collisions. To prevent this, the base station (BS) gives each device a counter. A device only responds to a downlink (DL) signal, like a Synchronization Signal Block (SSB, a periodic broadcast signal that helps devices detect the BS and align their timing before they start sending data), when its counter reaches zero. If the counter has not reached zero yet, the device waits for the next signal. Each time the device receives a signal, it reduces the counter or lets the timer count down. This spreads out the devices' responses so they do not all transmit at once. The reader can also assign different counters or timers for different transmission types or different readers, allowing better control even when many devices are present.





◀ WO2026022613A1

Uplink, downlink and joint uplink-downlink radio link failure prediction

Declared in TS 38.300, and TS 38.331 within the C-V2X standard.

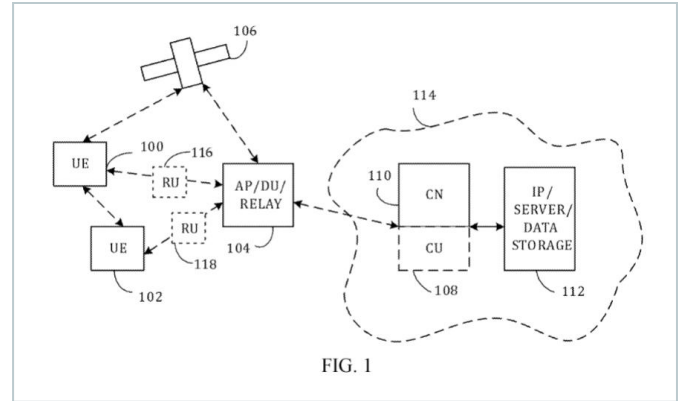


FIG. 1

The patent describes a technique where a terminal device uses machine learning (ML) models to predict radio link failures in the uplink (UL), downlink (DL), or both before they actually occur, helping prevent service disruptions. The terminal first reports its prediction capabilities to the network node, which then configures it with suitable ML modes and parameters. Using UL and DL measurements such as retransmission counts, random-access attempts, block-error rates, or reference-signal quality, the terminal estimates the likelihood of a future radio link failure. When certain conditions are met, it sends the prediction results back to the network as probabilities or warning indicators. The network uses these early predictions to take preventive actions such as preparing a handover, adjusting cell selections, or switching from a primary UL to a supplementary UL configuration.

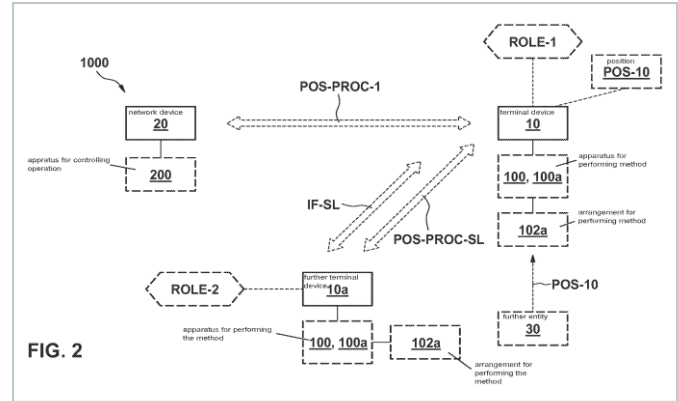




◀ **US2024053493A1**

Method and apparatus for a terminal device

Declared in **TS 38.331**, and **TS 38.214** within the **C-V2X standard**.



The patent describes a method to help a terminal device accurately report and verify its own position while working with other devices through direct sidelink communication, which refers to device-to-device communication without routing signals through the network, making the whole positioning process more flexible and reliable. It explains that the device can determine its initial location using different techniques such as Global Navigation Satellite System (GNSS) and then share this information with nearby devices along with an indication of its reliability. The device can switch roles on the fly, acting either as a reference point or as a target during sidelink positioning, and it can exchange positioning signals over interfaces like PC5 to help calculate distances precisely. It also allows continuous checks of the device's position to maintain accuracy over time.

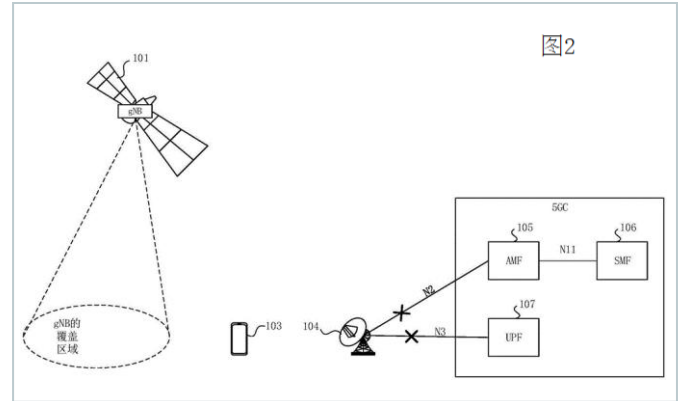




< **CN121151991A**

Satellite communication processing method and related device

Declared in **TS 23.501**, and **TS 23.502** within the **C-V2X standard**.



The patent describes how 5G satellite networks can avoid treating normal satellite movement as a fault by informing network elements when a satellite is leaving the coverage area. When mobility information shows that a satellite is exiting the service area, core functions like the Session Management Function (SMF, the system that manages data sessions) can delete sessions linked to that satellite or stop checking paths between the satellite's base station and the User Plane Function (UPF, the system that routes user data). This prevents expected GTP-U path breaks (the tunnel used to carry user data between network nodes) from being mistaken for equipment failures. The network can obtain this information through the Network Exposure Function (NEF, which helps the network receive mobility updates from satellite-tracking platforms). If the UPF reports path failures and the system knows the satellite has already left, those sessions can be removed.



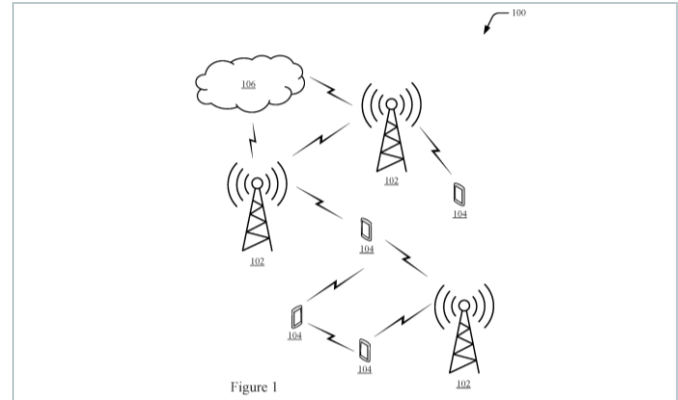


WO2025163525A1

Machine learning at a wireless device

Declared in TS 38.300 within the C-V2X standard.

Company name	Lenovo Singapore Pte Ltd
Inventors	Kothapalli Venkata Srinivas, Pourahmadi Vahid, Hindy Ahmed, Nangia Vijay
Priority date	31 Jan 2024
Publication date	07 Aug 2025



The patent talks about improving how machine learning (ML) models are trained at wireless communication devices (UE) by reducing generalization error (unseen-data error) without needing huge datasets or manual tuning. Instead of training one big model on all data, it divides the training samples into smaller subsets and trains separate model instances on each subset using supervised learning. The parameters learned from these smaller models are then combined to create one global ML model that performs better on new, unseen data. A wireless node (such as a base station) receives data samples from another node, splits them into subsets, and uses them to determine the model parameters that will be used by wireless devices such as a UE receiver. This approach lowers signaling overhead, cuts processing delays, and produces more reliable models for tasks like decoding, channel estimation, and beam selection.

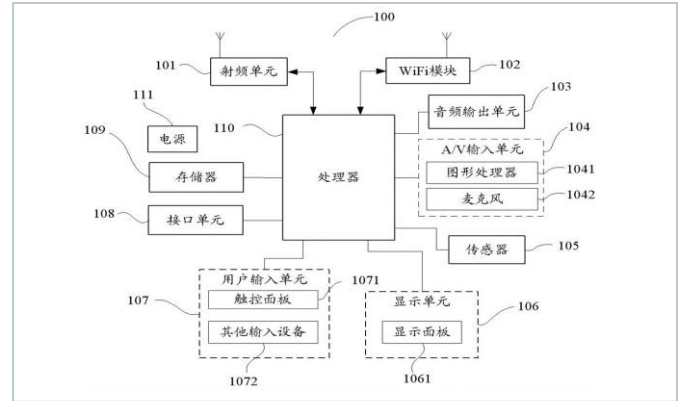




◀ **CN121194244A**

Processing method, communication device and storage medium

Declared in **TS 23.501**, and **TS 23.502** within the **C-V2X standard**.



The patent helps communication systems smoothly switch from one sensing function (SENF) to another when a device moves or when the network changes, since the original SENF may become too far away or unsuitable. When a change event occurs, such as an update in access network equipment or a new AMF address (Network address of the Access and Mobility Management Function), the old SENF sends all relevant sensing request information to a new SENF so that sensing tasks can continue. The AMF handles subscription and notifies the SENFs when such network changes occur. The system checks whether the current SENF can still support the ongoing tasks, and if not, it selects a new SENF based on its capabilities, load, energy efficiency, location, etc. Once the new SENF confirms that it has successfully received and taken over, the old SENF releases its resources.



The editor's shortlist

News of the month

Real World C-V2X Demo

5GAA Demonstrates the future of driving in the U.S.: From tolling to satellite connectivity

The 5G Automotive Association (5GAA) held demos in the U.S. showing real world connected vehicle technologies in action. The 5GAA members, including Autocrypt, Kapsch, Indra, Qualcomm, Valeo and others, demonstrated next generation tolling, safety and connectivity systems. The demos showed vehicles exchanging information with roadside units (RSUs) to enable smooth automatic toll payments. Satellite communication was also demonstrated, including a live voice call showing that vehicles can stay connected in remote areas. Safety demos featured cars receiving real-time traffic signal updates and road hazard alerts. AI-powered RSU sensors detected vehicles without connected technology and shared that data to enhance road safety. The event highlighted how Network C-V2X and Direct C-V2X can operate together on real roads.

Source

<https://5gaa.org/>



LG's Telematics Solution

LG Electronics unveils next-generation smart telematics solution at MWC Barcelona 2026

LG Electronics will reveal its new smart telematics module that combines a telematics control unit (TCU) and an antenna into one compact unit to improve in car connectivity, system performance and vehicle design. LG will host a private showcase for automakers and telecom partners to explore new business opportunities. The new module supports 5G, GPS, V2X and satellite signals while reducing signal loss and improving processing stability. It also cuts wiring complexity, speeds up assembly and removes the need for the usual shark fin antennas. The system meets major global safety and cybersecurity standards. LG is also expanding its work on transparent antennas developed with Saint Gobain Sekurit. Alongside this hardware, LG is strengthening its AlphaWare software to support safer and smarter AI powered vehicles.

Source

<https://www.lg.com/>



Real-Time Hazard Alerts

Kodiak integrates HAAS alert's safety cloud into autonomous trucking platform

Kodiak Robotics, a developer of autonomous long haul trucking technology, has integrated HAAS Alert's Safety Cloud system, which provides real time digital roadway hazard alerts. This system sends digital warnings to nearby drivers when a Kodiak truck is stopped at the roadside. The alerts are delivered directly into cars through infotainment systems and apps like Waze and Apple Maps. Drivers who receive these alerts typically slow down by about 17%, helping reduce crash risks. The feature adds another layer of protection on top of Kodiak's existing safety systems by placing hazard alerts directly in front of drivers. Kodiak may later expand the system so its trucks can also receive alerts from connected cars and emergency vehicles. Both companies say the partnership will improve safety for truck fleets and for everyone on the road.

Source

<https://www.truckinginfo.com/>



Satellite Powered V2X

New Univerty satellite constellation targets 5G for V2X in Europe

Univerty, a satellite company, plans to build a Very Low Earth Orbit network to give vehicles continuous connectivity for services like software updates, infotainment and future V2X features. The system is designed to work as part of regular mobile networks rather than as a separate satellite service. It aims to fix coverage gaps that occur in rural areas, mountainous regions and cross border routes where normal cellular networks struggle. The satellites will fly below 375 km to provide faster response times and use the same 2 GHz spectrum that mobile operators already use, so no special proprietary hardware is needed. The system supports uses ranging from high quality streaming to direct communication between the vehicle and the network. Future plans include V2X links for driver assistance and autonomous driving.

Source

<https://www.traffictchnologytoday.com/>



Partnership

Eviden and Almoviva join forces to secure deployments of Cooperative Intelligent Transport Systems (C-ITS) in Italy

Eviden has partnered with Almoviva to help Italy roll out nationwide C-ITS. These systems let vehicles communicate with road infrastructure and with each other to improve safety, reduce traffic and support cleaner transport. The work supports C Roads Italy, which is part of a larger EU program deploying these technologies across more than 20 countries. Almoviva will use Eviden's national scale C-ITS security system, known as a Public Key Infrastructure, within its MOOVA mobility platform. This technology ensures that every digital message shared between vehicles and roadside stations is secure, trusted and protected. The partnership ensures Italian operators receive local hosting, support and maintenance. It also provides a security system that is interoperable with EU standards and ready for both public and private users.

Source

<https://eviden.com/>



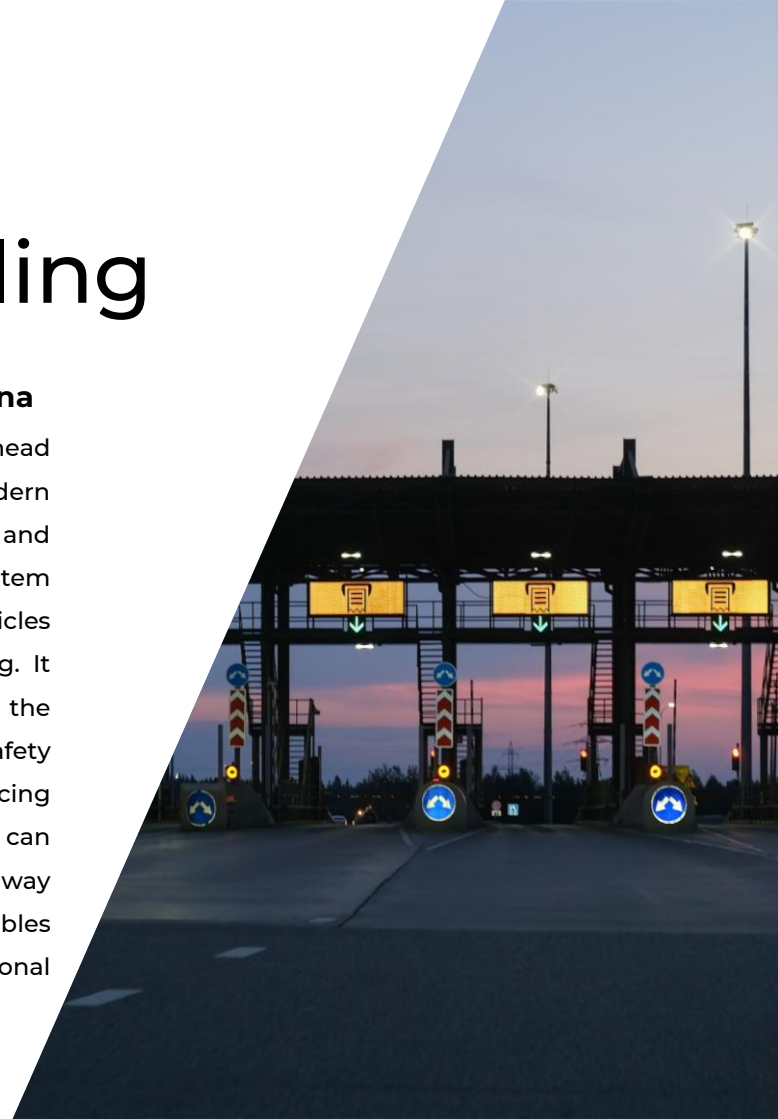
C-V2X based Tolling

Indra group marks U.S. Milestone with official opening of I-485 express lanes in north Carolina

Indra Group has officially launched its new all overhead tolling system. The opening marks the full start of a modern toll collection setup that uses only overhead equipment and removes the need for sensors in the road. The system includes 3D LiDAR that can detect, track and classify vehicles with high accuracy and also support safety monitoring. It also includes the first large scale use of C-V2X tolling in the U.S., letting connected cars receive real time toll and safety notifications. The tolling back office uses dynamic pricing that adjusts rates based on traffic levels. The new setup can detect unusual events such as pedestrians or wrong way drivers and alert connected vehicles instantly. It also enables smooth electronic payments and offers drivers an additional connected vehicle based payment option.

Source

<https://www.indragroup-usa.com/>



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patents maintained



~1 Million
trademarks managed



>60
years
of experience in IP



>20
global offices



>900
employees and
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