

5G-IANA: 5G Intelligent Automotive Network Applications

Application Functions
Network Functions
Network Applications



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Application Functions (AFs) Network Functions (NFs)

Video encoding/decoding



Name	Video encoding/decoding	Code	CAF-13 B-VNF-13	Domain	OBU+EDGE
Description	This AF encodes the video to be transmitted through the 5G network. Also responsible for decoding and playing the received video on a web application.				
Comments	Video resolution can be adapted to the 5G network conditions.				
Input required	<i>Coding:</i> video camera feed <i>Decoding:</i> H.264/HEVC over UDP protocol.				
Output provided	<i>Decoding:</i> H.264/HEVC over UDP protocol. <i>Coding:</i> video camera feed				
Examples of communicating VNFs	This AF is directly connected to the Long distance communication VNF, both in OBU and edge, to send the packets through 5G.				

Sensors' data capturing



Name	Sensors' data capturing	Code	CNF-06 C-VNF-06	Domain	OBU
Description	Collects from sensors data related to distance and angle to near obstacles.				
Comments					
Input required	Lidar raw input				
Output provided	Sensor (lidar) information: distance matrix				
Examples of communicating VNFs	This AF is directly connected to the Long distance communication VNF in the OBU to send the packets through 5G.				

Sensors' data analysis



Name	Sensors' data analysis	Code	CAF-43 B-VNF-47	Domain	EDGE
Description	Processes the information from the vehicle sensors and takes decisions regarding movement.				
Comments					
Input required	Sensor (lidar) information after data capturing: distance matrix				
Output provided	Distance and angle to near objects to be displayed Orders for stopping the vehicle if needed.				
Examples of communicating VNFs	Information obtained in specific directions (sub-sectors) are sent to the warning service AF. Also constantly exchanging information from the long distance communication NF.				

Object detection with Deep Learning



Name	Object detection with Deep Learning	Code	CAF-40 B-VNF-44	Domain	EDGE
Description	The video captured is processed on the edge to detect pedestrians, cars, and/or road elements such as traffic signals.				
Comments	It permits to comply with traffic regulations and avoid accidents.				
Input required	H.264/HEVC video over UDP protocol				
Output provided	Video processed with pedestrians, cars and traffic signals highlighted Real-time information on objects detected				
Examples of communicating VNFs	This AF needs the video coming from the long distance communication NF, processes it and sends it to the warning service AF to show what is detected in real-time				

Vehicle condition warning service



Name	Vehicle condition warning service	Code	CAF-41 B-VNF-45	Domain	EDGE
Description	Representation of warning signals and alerts in the user interface.				
Comments	Offers additional information to the driver, increasing safety.				
Input required	Real-time information on objects detected in the video feed Information from sensors' data analysis obtained in specific directions (sub-sectors)				
Output provided	Real-time warning images and sounds showed in a graphical interface				
Examples of communicating VNEs	This AF is continuously receiving information from the sensors' data analysis AF and video from the object detection AF				

Remote driving central control



Name	Remote driving central control	Code	CNF-17 B-VNF-17	Domain	EDGE/cloud
Description	This AF is the responsible of collecting the information from the driver. Uses a steering wheel and sends it to the server to be processed by the actuator.				
Comments					
Input required	Wheel/pedals inputs (angle, buttons, etc.)				
Output provided	Interactive commands in real time from these inputs (JSON orders in X,Y)				
Examples of communicating VNFs	The commands provided by the driver are sent to the actuator NF, which will translate them into orders to the vehicle.				

Remote driving module



Name	Remote driving module	Code	CAF-49 B-VNF-61	Domain	OBU
Description	This AF receives the orders from the actuator and moves the vehicle accordingly.				
Comments	It also stops the vehicle when needed.				
Input required	Directions in X,Y to move the vehicle (ROS) Stop signal if needed.				
Output provided	Wheel and engine orders to move				
Examples of communicating VNFs	This AF needs the orders coming from the long distance communication NF				

Actuator interface



Name	Actuator interface	Code	CNF-39 C-VNF-08	Domain	EDGE
Description	Receives the commands from the user and generates the control order in a language understood by the vehicle.				
Comments	Acts as a translator.				
Input required	Interactive commands in real time from these inputs (JSON orders in X,Y)				
Output provided	ROS socket JSON				
Examples of communicating VNFs	This NF needs the inputs from the remote driving central control AF and communicates directly with the long-distance communication NF.				

Maneuver Planning



Name	Manoeuvre Planning	Code	CAF-12 B-VNF12	Domain	MEC
Description	Gets configuration data from the Subscription Service (CAF-16/B-VNF16) and receives poses and trajectories from the Vehicle Interface (C-VNF04). Then, it issues manoeuvre coordination replies after having calculated the best trajectories every vehicle should follow for a safe and efficient travel.				
Comments	This VNF is able to coordinate a variable number of vehicles and should be agnostic to them being autonomous, human-driven or simulated				
Input required	Vehicle poses and destinations, geospatial data of the local road network				
Output provided	Instructions for the movement of each subscribed vehicle as data compatible with ETSI manoeuvre coordination messages				
Examples of communicating VNFs	This VNF is designed to communicate with CAF-16/B-VNF16 to understand the currently involved vehicles. It also communicates with B-VNF04 by sending planned manoeuvre data to it and receiving MCMs.				

Subscription Service



Name	Subscription Service	Code	CAF-16 B-VNF16	Domain	Cloud
Description	The service enables the enrolling of vehicles to the MCAD nApp to let them participate to the manoeuvre coordination.				
Comments	This VNF collects information about the vehicles (represented by their respective OBUs), both real and simulated, registered to the service.				
Input required	OBU registration requests				
Output provided	List of subscribed vehicles, configuration information for MCAD				
Examples of communicating VNFs	CAF-12/B-VNF12 relies on this VNF to provide information on the OBUs that have to be managed				

Vehicle Abstraction Service



Name	Vehicle Abstraction Service	Code	B-VNF55	Domain	OBU
Description	This VNF guarantees protocol compatibility between vehicle and the Vehicle Interface (C-VNF04).				
Comments	This VNF will adapt incoming/outgoing data to alleviate any discrepancies between C-VNF04 and the protocols utilized in the vehicle (real or simulated).				
Input required	Data to/from C-VNF04 from/to vehicle subsystems				
Output provided	Data to/from C-VNF04 from/to vehicle subsystems				
Examples of communicating VNFs	This VNF is expected to work in synergy with C-VNF04				

AR Media Access Function



Name	AR Media Access Function	Code	CAF-10	Domain	Edge
Description	The AR media access function is an AR streaming application that relies on buffering and multi threading techniques in order to give access to multi users to different AR content such as 3D objects.				
Comments	The AR media access function is actually the interface between the socket application of MEC with the users and its own AR VNFs such as repository etc. It also facilitates the AR content delivery protocol of the nApp related to UC4.				
Input required	Socket communication with the clients running an AR content delivery protocol.				
Output provided	The output is the actual AR content streaming to the users.				
Examples of communicating VNFs	The AR media access function is communicating with AR content repository and vCache VNFs.				

360° Video Stream Endpoint



Name	360° Video Stream Endpoint	Code	CNF-11 B-VNF52	Domain	FAR EDGE
Description	This NF facilitates sending the 360° Video Stream from the Far Edge to Edge Cloud. This video stream has been edited by a video slicer and a module that masks sensitive privacy related parts of the video (e.g. car plates)				
Comments	Developed by HIT				
Input required	The 360° Video Stream, edited by relevant modules (see description)				
Output provided	The 360° Video Stream, edited by relevant modules (see description)				
Examples of communicating VNFs	This VNF provides a video stream to <i>360° Video Stream Cache (CNF-13 / B-VNF54)</i>				

360° Video Stream Cache



Name	360° Video Stream Cache	Code	CNF-13 B-VNF54	Domain	EDGE CLOUD
Description	This NF handles the 360° Video Stream and acts as a buffering mechanism that will be employed to maintain video fidelity to the end users, even in no network service availability scenarios				
Comments	The mechanism will cache video data of maximum 6s duration. Developed by HIT				
Input required	The 360° Video Stream, edited by relevant modules				
Output provided	Video Related Data for the <i>Load Balancer</i> AF, the video stream to the VR app				
Examples of communicating VNFs	<i>360° Video Stream Endpoint</i> (CNF-11 / B-VNF52)				

Foveated Rendering Data Broker



Name	Foveated Rendering Data Broker	Code	CNF-14 B-VNF55	Domain	EDGE CLOUD
Description	This VNF is a data broker that receives foveatic data (i.e. point of view) from the VR users and acts as broker for related modules located in the Far Edge				
Comments	Either an MQTT or AMQP data broker will be deployed. Developed by HIT				
Input required	Foveatic data i.e. coordinates mapped on a projection to the 360o video sphere, linked to a used ID				
Output provided	Foveatic data i.e. coordinates mapped on a projection to the 360o video sphere, linked to a used ID				
Examples of communicating VNFs	This VNF provides input from the <i>Foveated Rendering Sink</i> (CNF-12 / B-VNF53)				

Foveated Rendering Sink



Name	Foveated Rendering Sink	Code	CNF-12 B-VNF53	Domain	FAR EDGE
Description	This VNF receives foveatic data (i.e. “fixation points”) from the Field of View Predictor AF and provides it to the Video Slicer AF.				
Comments	Foveating imaging is a technique where image resolution, or amount of detail, varies across the image according to one or more "fixation points“. Developed by HIT				
Input required	Fixation points predicted from the Field of View Predictor AF (CAF-45 / B-VNF49)				
Output provided	Fixation points predicted from the Field of View Predictor AF				
Examples of communicating VNFs	This VNF receives input from the <i>Foveated Rendering Data Broker</i> (CNF-14 / B-VNF55)				

Log Reporting Service Data Broker



Name	Log Reporting Service Data Broker	Code	CNF-16 B-VNF57	Domain	CORE CLOUD
Description	A network function that exposes Use Case Related data e.g. location based data stored in the <i>UC-Specific Log Reporting Service AF</i> . This data is used either for UC specific functionalities and for debugging/monitoring purposes				
Comments	Developed by HIT				
Input required	Various UC related data (e.g. logs, positional data) from VR server, FoV Predictor & Video slicer.				
Output provided	Various UC related data (e.g. logs, positional data) from VR server, FoV Predictor & Video slicer.				
Examples of communicating VNFs	This NF receives input from the VR server (CNF-15 / B-VNF56), FoV Predictor (CAF-45 / B-VNF49) & Video slicer (CAF-25 / B-VNF25)				

VR Server Module



Name	VR Server Module	Code	CNF-15 B-VNF56	Domain	CORE CLOUD
Description	A authoritative Unity server that is the backbone the VR application facilitating the Virtual Bus Tour presented in UC3				
Comments	Developed by HIT				
Input required	A) request from a VR Client Application, properly configured to the server b) locational data from the AMQP Broker. This data is us to provide location specific information to the users inside the VR application				
Output provided	Logs concerning the status of the Server				
Examples of communicating VNFs	This VNF interacts with the <i>AMQP Broker</i>				

Privacy Masking Module



Name	Privacy Masking Module	Code	CAF-43 B-VNF47	Domain	Far Edge
Description	This AF applies privacy masking to the 360o video stream used in UC3, meaning that footage of pedestrians passing by, car plates etc. is blurred for anonymization.				
Comments	Developed by HIT				
Input required	Unedited 360o video stream				
Output provided	360o video stream where individual privacy related parts are masked				
Examples of communicating VNFs	This VNF communicates with <i>Livestream encoder AF (CAF-44 /B-VNF48)</i>				

Livestream Encoder



Name	Livestream Encoder	Code	CAF-44 B-VNF48	Domain	Far Edge
Description	This AF handles the video encoding i.e, compressions and re-encoding tasks. It receives information from the Active Network Monitoring Module to decide if compression is needed.				
Comments	Developed by HIT				
Input required	360o video stream where individual privacy related parts are masked produced by the Privacy Masking Module (CAF-43, B-VNF47)				
Output provided	Encoded 360o video stream				
Examples of communicating VNFs					

360o Video Slicer



Name	360o Video Slicer	Code	CAF-25 B-VNF25	Domain	Far Edge
Description	This AF masks the 360o video so that the parts where the users focus have high resolution while the remaining parts have low resolution.				
Comments	Developed by HIT				
Input required	Coordinates for the points of interest for each user				
Output provided	A masked 360o video				
Examples of communicating VNFs	360o Video Slicer receives input from the foveatic rendering sink				

Field of View Predictor



Name	Field of View Predictor	Code	CAF-45 B-VNF49	Domain	Far Edge
Description	This AF utilizes Deep Learning AI techniques to predict the future Points-of-View for the VR users				
Comments	Developed by HIT				
Input required	Current and historical Point-of-View coordinates				
Output provided	Prediction off future Point-of-View coordinates				
Examples of communicating VNFs	FoV Predictor receives current and historical Point-of-View coordinates from the foveatic rendering Data Broker (CNF-14 /B-VNF55)				

OBU Localization service



Name	OBU Localization service	Code	Not added in relevant inventory yet	Domain	EDGE
Description	This function will provide the location of the OBU as a service				
Comments	Developed by LINKS				
Input required	-				
Output provided	Location coordinates				
Examples of communicating VNFs	The OBU localization service will provide the coordinates of the OBU to the VR Server Module so it can provide location specific information				

Monitoring VNF



Name	Monitoring VNF	Code	CAF-30 B-VNF36	Domain	Edge Remote Cloud RSU
Description	Collecting data from the field (sensors, cameras, cooperative awareness service, etc.) and storing them. Also distributing data (including video streams) to 3rd parties, e.g., other VNFs.				
Comments	This VNF is able to receive all kinds of data via https and rtsp interface. Data are then stored and are exposed to interested consumers (other VNFs) via https, mysql and rtsp depending on the certain situation (i.e., type of data).				
Input required	https, rtsp				
Output provided	https, mysql, rtsp				
Examples of communicating VNFs	Monitoring VNF can collect data exposed by other VNF(s), as well as exposing data to other VNF(s), e.g., in UC 7, Monitoring VNF, among other sources, collects data sent by “Simulator of ETSI Cooperative Awareness Basic Service” VNF and exposes data to Analytics VNF and Streaming VNF.				

Analytics VNF



Name	Analytics VNF	Code	CAF-29 B-VNF35	Domain	Edge Remote Cloud
Description	Analytics VNF serves for data visualization and reports creation. Data visualization and report structure is based on customer requirements.				
Comments	Analytics VNF captures data making https or mysql requests to data storage, it does not store data itself. Output of the VNF, i.e., reports, can be accessed/downloaded via https.				
Input required	https, mysql				
Output provided	https				
Examples of communicating VNFs	Data that need to be analysed/visualized can be delivered to the Analytics VNF by another VNF (e.g., such as Monitoring VNF in case of UC 7). The consumer of the Analytics VNF's output is typically end user.				

Streaming VNF



Name	Streaming VNF	Code	CAF-31 B-VNF37	Domain	Edge Remote Cloud RSU
Description	Streaming VNF is a video proxy component receiving video stream from cameras and forwarding it to the end users.				
Comments	Works as a standalone function.				
Input required	https, rtsp				
Output provided	https, rtsp				
Examples of communicating VNFs	Streaming VNF is able to receive video stream from another VNF(s) and forwarding it to VNF(s) as well (e.g., in case of UC7, Streaming VNF receives video stream from Monitoring VNF).				

C-ITS messages Uu communication



Name	C-ITS messages Uu communication	Code	C-VNF02	Domain	OBU, RSU, MEC
Description	This VNF is in charge to transmit and to receive C-ITS messages for the Uu interface interacting with a Message Broker located on MEC or in the Cloud.				
Comments	This NF provides the functionalities of the Access, and the Networking & Transport layers as described in the ETSI EN 302 665). This NF follows the same approach used in the 5G-CARMEN project in which communications among vehicles via network (i.e., V2N2V) and between vehicles and the network (i.e., V2N) are performed using the Uu interface. An AMQP 1.0 Message Broker, which is located at the edge server, is used to exchange the C-ITS messages among the different actors involved (e.g., vehicles, roadside and edge server C-ITS applications).				
Input required	C-ITS messages to be transmitted				
Output provided	C-ITS messages that have been received				
Examples of communicating VNFs					

Vehicle interface



Name	Vehicle interface	Code	C-VNF04	Domain	OBU
Description	This VNF is in charge to interact with the vehicle network to exchange information between the vehicle and the OBU				
Comments	This VNF is specific to the vehicle on which the OBU is installed. It is not possible to provide generic VNF. The VNF could use Ethernet or CAN-bus interface				
Input required	Data to be sent to the vehicle's network				
Output provided	Data received from the vehicle's network				
Examples of communicating VNFs					

Decentralized Environmental Notification Service



Name	Decentralized Environmental Notification Service	Code	B-VNF01	Domain	OBU, RSU, MEC
Description	This VNF implements the functionalities of the ETSI Decentralized Environmental Notification Service (ETSI EN 302 637-3 V1.3.1)				
Comments	Decentralized Environmental Notification Messages (DENMs) provide alerts about possible hazards and events				
Input required	Trigger information as defined by the ETSI standard				
Output provided	Information of received DENMs				
Examples of communicating VNFs					

Cooperative Awareness Basic Service



Name	Cooperative Awareness Basic Service	Code	B-VNF02	Domain	OBU, RSU, MEC
Description	This VNF implements the functionalities of the ETSI Cooperative Awareness Basic Service in compliance to standard ETSI EN 302 637-2 V1.4.1				
Comments	Cooperative Awareness Messages (CAMs) provide information about the vehicle status, its position and dynamics at the OBU, while at the RSU they signal the presence of a protected communication zone. CAM generation is performed only on the OBU and on the RSU, at the MEC server this VNF is used only to provide information from received CAMs				
Input required	Information about vehicle status, position and its dynamics				
Output provided	Information of received CAMs				
Examples of communicating VNFs					

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Collective Perception Service



Name	Collective Perception Service	Code	B-VNF03	Domain	OBU, RSU, MEC
Description	This VNF implements the functionalities of the ETSI Collective Perception Service that is defined in the ETSI TS 103 324				
Comments	Collective Perception Messages (CPMs) provide information retrieved from the processing of raw sensors data (e.g., object type, object dynamics, free spaces)				
Input required	Information obtained from the processing of local sensors' data and other potential data sources.				
Output provided	Information of received CPMs				
Examples of communicating VNFs					

Manoeuvre Coordination Service



Name	Manoeuvre Coordination Service	Code	B-VNF04	Domain	OBU, MEC
Description	This VNF implements the functionalities of the ETSI Manoeuvre Coordination Service. This service is currently under description and specification respectively in the documents ETSI TR 103 578 and ETSI TS 103 561				
Comments	Manoeuvre Coordination Messages (MCMs) are used by vehicles to share their intentions about manoeuvres and to coordinate manoeuvres				
Input required	Information about planned manoeuvres				
Output provided	Information of received MCMs				
Examples of communicating VNFs					

Traffic Light Manoeuvre Service



Name	Traffic Light Manoeuvre Service	Code	B-VNF05	Domain	RSU, MEC
Description	This VNF implements the functionalities of the ETSI Traffic Light Manoeuvre Service in compliance to standard ETSI TS 103 301 V1.3.1				
Comments	The Signal Phase And Timing Extended Messages (SPATEMs) provide information related to the traffic light controller of a specific intersection such as the current phases of the traffic lights, the remaining time to the change to next phases				
Input required	Information received in input from the traffic light controller				
Output provided	Information of received SPATEMs				
Examples of communicating VNFs					

Road and Lane Topology Service



Name	Road and Lane Topology Service	Code	B-VNF06	Domain	RSU, MEC
Description	This VNF implements the functionalities of the ETSI Road and Lane Topology Service in compliance to standard ETSI TS 103 301 V1.3.1.				
Comments	MAP Extended Messages (MAPEMs) that provide information related to the geometry of a given intersection and the topology of related lanes				
Input required	Information received in input about the intersection topology (typically information is static)				
Output provided	Information of received MAPEMs				
Examples of communicating VNFs					

Infrastructure to Vehicle Information Service



Name	Infrastructure to Vehicle Information Service	Code	B-VNF07	Domain	RSU, MEC
Description	This VNF implements the functionalities of the ETSI Infrastructure to Vehicle Information Service in compliance to standard ETSI TS 103 301 V1.3.1				
Comments	Infrastructure to Vehicle Information Messages (IVIMs) provide information about road signage				
Input required	Information received in input about the road signage (typically information is static)				
Output provided	Information of received IVIMs				
Examples of communicating VNFs					

Enhanced Local Dynamic Map Service



Name	Enhanced Local Dynamic Map Service	Code	B-VNF09	Domain	OBU, RSU, MEC
Description	This VNF implements a Local Dynamic Map (LDM) Service that provides information to applications about local events, real time dynamic object information and other nearby connected vehicles				
Comments	LDM provides subscription methods to VNFs that are interested into the retrieval of information				
Input required	Information provided by applications and received at the OBU (e.g., from DENMs, CPMs)				
Output provided	Information contained in the LDM				
Examples of communicating VNFs					

Events Relevance Service



Name	Events Relevance Service	Code	B-VNF10	Domain	OBU
Description	This VNF selects the events that are relevant to the vehicle according to its trajectory				
Comments					
Input required	Events information from DENMs				
Output provided	Relevance of the events with respect to current vehicle's trajectory				
Examples of communicating VNFs					

Multi-object detection and tracking



Name	Multi-object detection and tracking	Code	B-VNF15/16	Domain	
Description	This VNF has the functionality of detecting and tracking objects from a video stream.				
Comments	It provides the type of the detected object, the bounding box details of the frame, and the tracking information. Two versions of this VNF are available: i) CPU-based version and ii) GPU-based version				
Input required	Video stream				
Output provided	Object detection and tracking information				
Examples of communicating VNFs					

Simulator of Cooperative Awareness Basic Service



Name	Simulator of Cooperative Awareness Basic Service	Code	B-VNF31	Domain	RSU, MEC
Description	This VNF simulates the same functionalities of the B-VNF02 “ETSI Cooperative Awareness Basic Service”.				
Comments	It generates CAM messages considering synthetic information of vehicle’s position and dynamics provided to the VNF from an external client (e.g., path of the vehicle provided using a file)				
Input required	File describing vehicle’s path				
Output provided	CAMs messages sent to a specific endpoint (e.g., Message Broker)				
Examples of communicating VNFs					

Virtualized Cache (vCache)



Name	Virtualized Cache (vCache)	Code	CAF-20 B-VNF22	Domain	Edge Far Edge
Description	The Virtualized Cache is based on the Apache Traffic Server (ATS) open-source software, which can be configured to act as a reverse proxy. The function currently offers also an embedded RESTful server that enables its run-time configuration (Day1/Day2). In addition, it embeds also a Telegraf agent to export metrics.				
Comments	This vCache can be used to build the typical Content Delivery Network (CDN). In case of video streaming, to work properly the streaming protocol should stand on-top of HTTP/TCP (e.g., MPEG-DASH), since the vCache performs HTTP requests' mapping to be able to get the video content. If deployed in the Far Edge, the Load Balancer cannot be integrated, since load balancing functionalities are not needed.				
Input required	Content cached through HTTP requests' mapping.				
Output provided	Content provided through HTTP requests' mapping, statistics (ATS exposes an RESTful end-point to get statistics).				
Examples of communicating VNFs	The vCache can communicate with other vCaches in a CDN hierarchy or with an Origin Streaming Server, which streams over HTTP/TCP. It's possible to put a Load Balancer service in front of the vCaches hierarchy to apply policies for the ditribution of streaming requests coming from multiple clients.				

UHD Origin Streaming Server



Name	Origin Server	Code	CAF-21 B-VNF23	Domain	Remote Cloud
Description	The UHD Origin Streaming Server is based on the PLEX community version. It's an UHD-capable Origin Server that performs adaptive streaming using MPEG-DASH.				
Comments	This Origin Server can be used to build the typical Content Delivery Network (CDN). It's the element in the CDN hierarchy that embeds the media library and act as the source of the available contents.				
Input required	Media library.				
Output provided	Content provided through MPEG-DASH, statistics can be exported by using the Tautulli tool.				
Examples of communicating VNFs	The Origin Server can communicate with the vCaches in a CDN hierarchy as the principal source of media contents that are provided through MPEG-DASH/HTTP/TCP.				

Load Balancer



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Name	Load Balancer	Code	CAF-22 B-VNF24	Domain	Edge
Description	The Load Balancer is based on the open-source HAPROXY software. It provides load balancing functionalities for applications based on HTTP/TCP, basically performing HTTP redirects towards application servers. The Load Balancer can be configured to apply different policies and offers a RESTful server for its run-time configuration (Day1/Day2), e.g., to add an new application server to its farm.				
Comments	This Origin Server can be used to build the typical Content Delivery Network (CDN), balancing clients' requests towards the last layer of vCaches in the CDN hierarchy.				
Input required	HTTP requests.				
Output provided	HTTP redirects towards the selected application servers.				
Examples of communicating VNFs	The Load Balancer can communicate with the vCaches in a CDN hierarchy to redirect HTTP/TCP requests.				

Elasticsearch Stack



Name	Elasticsearch Stack (ELK)	Code	CAF-23 B-VNF26	Domain	-
Description	The Elasticsearch Stack is a monitoring framework composed by different tools with different functionalities. Beats are data/log/event collector, Logstash is a data aggregator and Elasticsearch is time-series DB.				
Comments	A Beat agent can be packaged within every VNF or deployed as a VNF to be able to export relevant data. Logstash and Elasticsearch are more suitable to be integrated as platform's functionalities.				
Input required	Depends on the kind of data/metrics/statistics that are of interest. Several input plugin can be configured.				
Output provided	Depends on the kind of information that should be exposed. Several output plugin can be configured.				
Examples of communicating VNFs	E.g., Filebeat can collect relevant rows from logs and can export the related events to Logstash.				

Telegraf



Name	Telegraf	Code	CAF-24 B-VNF27	Domain	-
Description	Telegraf is a monitoring agent to export data/metrics/statistics through the usage of plugins.				
Comments	The Telegraf agent can be packaged within every VNF or deployed as a VNF to be able to export relevant data.				
Input required	Depends on the kind of data/metrics/statistics that are of interest. Several input plugin can be configured.				
Output provided	Depends on the kind of information that should be exposed. Several output plugin can be configured.				
Examples of communicating VNFs	E.g., Telegraf can collect data from the interfaces of a VM/container running another VNF and can expose relevant information through the integration with a time-serie DB or a message bus.				

Virtualized DNS



Name	Virtualized DNS (vDNS)	Code	CNF-08 B-VNF25	Domain	Edge Remote Cloud
Description	The vDNS is based on the open-source BIND9 software. The DNS is packaged with a RESTful server to enable its run-time configuration (Day1/Day2).				
Comments	It's actually packaged together with the Load Balancer.				
Input required	Request for a domain name resolution over HTTP.				
Output provided	Domain name resolution.				
Examples of communicating VNFs	-				

Network Monitoring



Name	Network Monitoring	Code	CAF-41 B-VNF43	Domain	Far Edge Edge
Description	The Network Monitoring analyses and records all the network traffic on the network and provide a single point of access to the data stored.				
Comments	Needs to be deployed on the network to be analysed.				
Input required	The network traffic.				
Output provided	The recorded data.				
Examples of communicating VNFs	The Virtualized IPS/IDS (CNF-11) use the data collected to detects and prevents suspicious behaviours on the network.				

Position and time service



Name	Position and Time Service	Code	B-VNF08	Domain	OBU, RSU, MEC
Description	This VNF implements the Position and Time Service in order to offer similar functionalities to the ETSI Position and Time (PoTi) service specified in ETSI EN 302890-2				
Comments	On the OBU the VNF provides time and position retrieved from a GNSS RTK receiver.				
Input required	Information from GNSS				
Output provided	Position and Time information				
Examples of communicating VNFs	In UC5, this VNF will communicate on the OBU with B-VNF01 and C-VNF03 and will interact with the hazardous event detection & display VNFs. It will be used to provide high accuracy position & time data (RTK) for the detection of hazardous driving events.				

Hazardous event receiver and display



Name	Hazardous event receiver and display	Code	B-VNF-52	Domain	OBU
Description	This VNF be responsible for receiving information on road risk level change and display a relevant warning to the driver. Will be combined with an NF developed in UC2 for the display (TBC).				
Comments	Offers warning to the driver.				
Input required	High risk data provided by the Hazardous Driving Behaviour Detection VNF and Position and Time information provided by B-VNF08 and smartphone sensors.				
Output provided	A message displaying high risk warnings.				
Examples of communicating VNFs	This VNF will communicate with the driver's smartphone, with C-VNF03 and B-VNF01. It will be deployed on the OBU.				

Hazardous driving behaviour detection



A

Name	Hazardous driving behaviour detection	Code	B-VNF-53	Domain	OBU
Description	This VNF will be responsible for detecting and evaluating hazardous driving events (harsh braking, harsh acceleration, speeding, mobile use)				
Comments	Detects hazardous driving behaviour.				
Input required	Position and time information provided by B-VNF08 and smartphone sensors for calculating hazardous driving events.				
Output provided	High-risk events that will be transferred to the Hazardous event receiver and display VNF.				
Examples of communicating VNFs	This VNF will communicate with the driver's smartphone with C-VNF03 and B-VNF01. It will be deployed on the OBU.				

Aggregated road risk level



A

Name	Hazardous driving behaviour detection	Code	B-VNF-54	Domain	OBU
Description	ML model to be trained on the edge for the assessment of the risk level of a road network, based on aggregated data (from sources such as telematics service) and enriched by real-time data				
Comments	-				
Input required	Position and time information provided by B-VNF08 and hazardous events detected by B-VNF-53.				
Output provided	Road risk level information based on aggregated data				
Examples of communicating VNFs	This VNF will live on the Edge server and will communicate with B-VNF-52 to provide relevant information to drivers.				

Elastic search service



Name	Elasticsearch Stack (ELK)	Code	B-VNF26	Domain	Cloud
Description	The Elasticsearch Stack is a monitoring framework composed by different tools with different functionalities. Beats are data/log/event collector, Logstash is a data aggregator and Elasticsearch is time-serie DB.				
Comments	A Beat agent can be packaged within every VNF or deployed as a VNF to be able to export relevant data. Logstash and Elasticsearch are more suitable to be integrated as platform's functionalities. Will be provided by NXW.				
Input required	Depends on the kind of data/metrics/statistics that are of interest. Several input plugin can be configured.				
Output provided	Depends on the kind of information that should be exposed. Several output plugin can be configured.				
Examples of communicating VNFs	In UC5, this AF will be deployed on the cloud and will communicate with the NFs deployed on the edge. It will function for log-keeping purposes.				

Log reporting service



Name	Log Reporting Service	Code	B-VNF11	Domain	OBU, Cloud
Description	This VNF retrieves the information to insert in the log and it sends the log to the proper edge/cloud logging service.				
Comments	The log details are defined by the nApp implementing the log service on the vehicle, which is also in charge to trigger the sending of the log. The Log Reporting Service may buffer the information that may be requested to be inserted in a log over a predefined time period (e.g., this VNF can register the position of the vehicle in the last five minutes).				
Input required	Log information to be sent.				
Output provided	Acknowledgement from edge/cloud logging service				
Examples of communicating VNFs	In UC5, this AF will be deployed on the cloud and will communicate with the NFs deployed on the edge. It will function for log-keeping purposes.				

ML Preprocessing Node



Name	ML Preprocessing Node	Code	CAF-48 B-VNF60	Domain	OBU
Description	The VNF transforms the acquired raw data into an ML-specific dataset e.g. for predictive QoS into a spatio-temporal network latency data-set.				
Comments	Includes standard preprocessing functionalities such as data cleaning, normalization, split (train-validation-inference), division into batches, etc.				
Input required	Raw data records from Network Monitoring VNF				
Output provided	ML-specific datasets, ready to be trained/infered				
Examples of communicating VNFs	Receives input from Network Monitoring VNF and provides output to either the Training Agent (for training) or the Inference Node (for inference).				

ML node-Training Agent



Name	ML node-Training Agent	Code	CAF-19 B-VNF21	Domain		OBU	
Description	The VNF trains the model using a locally collected data set. This model is sent to the aggregation VNF. After the aggregation, the VNF receives a new globally trained model for further training.						
Comments							
Input required	Dataset from the Preprocessing VNF						
Output provided	Locally trained ML model						
Examples of communicating VNFs	This VNF communicates with the Preprocessing VNF to get the dataset for training and also communicates with the aggregation node to exchange models.						

DML Aggregation Node



Name	DML Aggregation Node	Code	CAF-18 B-VNF20	Domain	EDGE
Description	The VNF receives the locally trained DML models from all the worker nodes(edges) and aggregates them.				
Comments	The type of aggregation, available workers and ML-related policies are provided by the DMLO and are communicated to the DML AggNode.				
Input required	Locally trained DML models from worker nodes and aggregation method from DMLO.				
Output provided	Aggregated global model				
Examples of communicating VNFs	Aggregation Node communicates with ML node Training agent VNF on all working nodes to get locally trained models and to send global model.				

QoS Prediction



Name	QoS Prediction	Code	CAF-26 B-VNF30	Domain	OBU
Description	This VNF is based on the trained Distributed ML model present at the Edge node.				
Comments	An LSTM prediction model is trained on each edge node and aggregated at the DML server. This aggregated global model is then transmitted to all the Edge nodes for training and inference.				
Input required	ML model, ML-specific dataset (Spatial position and time for QoS prediction)				
Output provided	Predicted QoS (based on ML model latency or rate) value				
Examples of communicating VNFs	This VNF communicates with the AggNode VNF to acquire a trained ML model and using (cleaned) datasets from the Preprocessing VNF produces predictions.				

Network Applications (nApps)

Real Time Stream Delivery



Component name	Type
Video Encoding/Decoding	AF
Long-distance Data Communication	NF

The NFs and AFs in this nApp handle video encoding/decoding and streaming. AF#1 can be easily modified to use different protocols (RTP,RTSP) and codecs (H264,VP8,VP9).

Object Detection Stream and Data Delivery:



Component name	Type
Video Encoding/Decoding	AF
Long-distance Data Communication	NF
Object Detection with Deep Learning	AF
Vehicle Condition Warning Service	AF

The NFs and AFs in this nApp handle video encoding/decoding and streaming. Also applies an AI algorithm to detect objects in the video streaming. Video Encoding/Decoding AF can be easily modified to use different protocols (RTP,RTSP) and codecs (H264,VP8,VP9). Object Detection with Deep Learning AF can be replaced or modified with other AI algorithms.

AGV Data Processing, Communication and Control



Component name	Type
Remote Driving Module	AF
Sensor's Data Capturing	NF
Long-Distance Data Communication	NF
Sensor's Data Analysis	AF
Actuator Interface	NF

The NFs and AFs in this nApp manages the communication with the vehicle and the processing of data from its sensors, making movement decisions. Sensor's Data Analysis AF can be modified to include data of new sensors in the vehicle and process their information.

Remote Driving – UC1



Component name	Type
Remote Driving Module	AF
Video Encoding/Decoding	AF
Object Detection with Deep Learning	AF
Remote Driving Central Control	AF
Remote Driving Module	AF
Sensor's Data Capturing	NF
Long-Distance Data Communication	NF
Sensor's Data Analysis	AF
Actuator Interface	NF

This nApp is made up of the entire chain of Afs/NFs for remote driving of a vehicle. It provides a user interface that facilitates vehicle control, offering a warning system and detection of nearby objects and traffic signs to help driving task. AF#5 can be easily modified to suit the needs and requirements of the user.

MCAD Edge Node



Component name	Type
Manoeuvre Planning	AF
C-ITS messages Uu communication	NF
ETSI Manoeuvre Coordination Service	NF

The nApp provides access to the MCAD Edge Node for a vehicle to participate in the manoeuvre coordination service. The essential component is Vehicle Interface AF. Vehicle Abstraction Service NF can be substitute with a vehicle-specific interface. It could be even replicated to interface more than one functional vehicle node at a time. C-ITS messages Uu Communication NF and ETSI Manoeuvre Coordination Service NF can be changed to host a different communication layer.

MCAD Rover Node



Component name	Type
Vehicle Interface	AF
Vehicle Abstraction Service	NF
C-ITS messages Uu communication	NF
ETSI Manoeuvre Coordination Service	NF

The nApp provides a manoeuvre coordination service among registered MCAD Rover Nodes. The core component is the AF #2. NF #2 and NF #3 can be changed to host a different communication layer. In that case the AF #2 can be eventually replicated for hosting load distribution mechanisms.

MCAD Subscription Service



Component name	Type
Subscription Service	AF
The nApp provides a web interface to MCAD service configuration and supervised junctions or vehicles OBUs registration. The Subscription Service can be easily updated or changed with a different web service or webapp.	

AI Enhanced Video Stream Delivery



Component name	Type
Privacy Masking Module	AF
LiveStream Encoder	AF
Video Slicer	AF
Field of View Predictor	AF
UC-Specific Log Reporting Service	AF
360 video Stream Endpoint	NF
360 Video Stream Cache	NF
Foveated Rendering Data Broker	NF
Foveated Rendering Sink	NF
VR Server Module	NF
Active Network Monitoring Module	NF
Log Reporting Service Data Broker	NF

The NFs and AFs in this nApp handle video encoding and streaming. Video Slicer AF and Field of View Predictor AF can be easily modified to allow the addition of other AI algorithms to interact with the video data.

Video enabled VR Client



Component name	Type
360 video Stream Endpoint	NF
360 Video Stream Cache	NF
Foveated Rendering Data Broker	NF
The NFs in this nApp provide a VR service that can utilize live video as a background.	

Active Network Monitoring Module



Component name	Type
Active Network Monitoring Module	NF
Active Network Monitoring Module NF monitors the network for bandwidth availability and can be utilized as a service for any other nApp that would benefit from such a functionality.	

AR Content delivery



Component name	Type
Virtualized Cache	AF
AR content repository	AF
Load balancer	AF
Network Monitoring	AF
C-ITS messages Uu communication	NF
AR media access function	NF

The AR media access function NF and Virtualized Cache AF with AR content repository AF plus Load balancer AF in this nApp handle AR objects streaming. Network Monitoring AF with C-ITS messages Uu communication NF are related to the network monitoring and connection.

Hazardous driving event detection



Component name	Type
Position and time service	AF
Hazardous driving behaviour detection	AF
Elastic search service	AF
Log reporting service	AF
C-ITS messages Uu communication	NF
ETSI decentralized environmental notification service	NF

The NFs and AFs in this nApp handle hazardous driving behaviour detection and risk event notification. Hazardous driving behaviour detection AF and Elastic Search service AF interface the smartphone and OBU and can be easily modified to allow the addition of other AI algorithms to interact with the driving behaviour data.

Hazardous driving event notification



Component name	Type
Position and time service	AF
Hazardous event receiver and display	AF
Hazardous driving behaviour detection	AF
Elastic search service	AF
Log reporting service	AF
C-ITS messages Uu communication	NF
ETSI decentralized environmental notification service	NF
This nApp will subscribe to events from ETSI decentralized environmental notification service NF and will identify the appropriate ones to display to the driver.	

Video Stream Delivery



Component name	Type
Monitoring VNF	AF
Streaming VNF	AF
Providing a complete end-to-end video streaming service from camera on one end to UE/display on the other end (e.g., UE streams over 5G)	

Environmental/IoT monitoring



Component name	Type
Monitoring VNF	AF
Analytics VNF	AF
End-to-end service for collecting any kind of environmental or other data (via IoT sensors, e.g., temperature, humidity, CO level, etc.), storing, and representing them in multiple ways (processed by statistical methods, raw data; graphical UI, textual – depends on customer/user needs).	

ITS communication nApp



Component name	Type
C-ITS Messages Basic Services	NF
Uu C-ITS messages communication	NF
Enhanced Local Dynamic Map Service	NF
Position and Time Service	NF
Event relevance Service	NF

This nApp implements the functionalities of the Intelligent Transport Systems (ITS) communication architecture that is introduced in the ETSI EN 302 665. The ITS communication is a system that has been defined for communication in the transportation system. It is used for communication among vehicles and among vehicles, road-side infrastructure (i.e., Road Side Unit (RSU)), and the network infrastructure (i.e., edge server).

Simulator of ETSI Cooperative Awareness Service



Component name	Type
Simulator of ETSI cooperative Awareness Service	AF
Simulating presence of multiple vehicles by generating certain vehicle related parameters.	

Vehicle Monitoring



Component name	Type
Monitoring VNF	AF
Analytics VNF	AF
Cooperative Awareness Service	AF
Enhanced Local Dynamic Map Service	AF
C-ITS message Uu communication	NF
Collecting (via OBU), storing, and representing various parameters of the vehicle.	

Position and Time Service



Component name	Type
Position and time service	AF
Collects the position information of the OBUs which might be help for client selection for DML tasks.	

Predictive QoS



Component name	Type
QoS Prediction	AF
<p>Based on the trained Distributed ML model present at the Edge node. An LSTM prediction model is trained on each edge node and aggregated at the DML server. This aggregated global model is then transmitted to all the Edge nodes for training and inference.</p>	

Obtain training data



Component name	Type
ML pre-processing	AF
Network monitoring	AF
This nApp collects the network status such as round trip time, and data rate, and processes it suitable for training.	

DML Training



Component name	Type
ML node-training agent	AF
DML aggregation node	AF
This nApp trains the local models of each OBU with the training data collected by the previous nApp. The trained models from all the OBUs are further aggregated at the Edge to form a single Global model.	