# Vehicular Edge Computing

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- Urban vehicular network is viewed as a core component of intelligent transportation systems, covering regions of traffic safety, localization and navigation, high-efficiency information sharing and spread, and so on.

- Over 150 million cars on roads will be connected by 2020.
  – Since each car generates on average 30 TB data a day, it challenges the ever-saturating wireless bandwidth.

- Increasing number of vehicles on roads is promising to alleviate the traffic burden of cellular networks via intelligent management.

- Traditional ad hoc vehicle-to-vehicle (V2V) communication pattern suffers from intermittent connectivity, making quality of services and ultra-low latency requirements challenging.

- Bandwidth of cellular networks is limited and primarily controlled by network operators.

- Mobile cloud computing is time consuming and expensive for real-time traffic uploading in vehicular networks.

- Vehicular cloud computing (VCC) is aimed at employing network resources efficiently so that vehicles are not only resource consumers but also resource providers.

- The ever-increasing services and applications in vehicular networks call for huge computing resources and real-time feedback, challenging the resource-limited vehicles and centralized traffic management mechanisms, especially during traffic peak times in a citywide area.

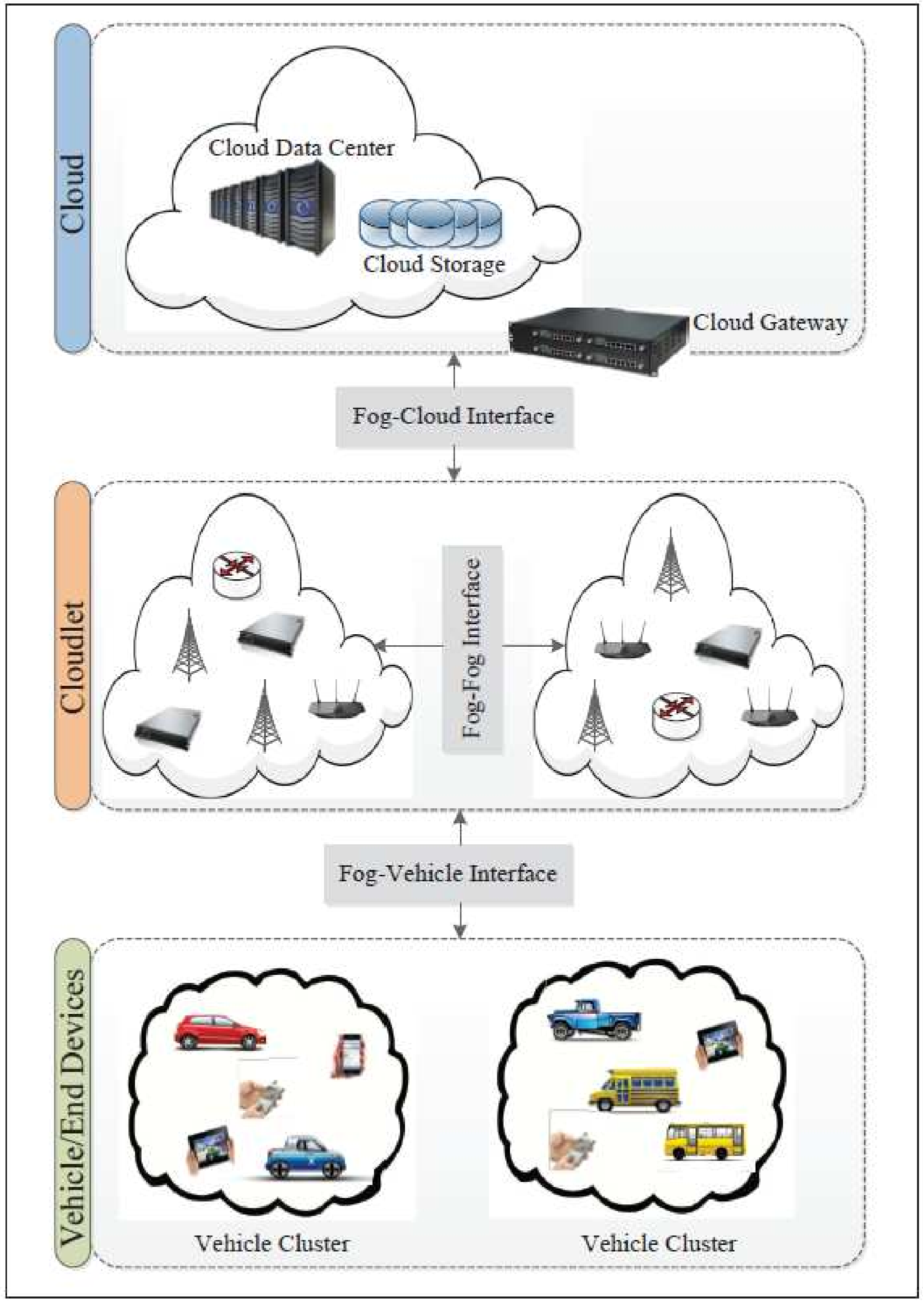
- Fog computing extends the facility of cloud computing from the center to edge networks. By facilitating the communication, computing, and networking close to end terminals, fog computing is flexible and highly efficient for optimizing network resources from a local viewpoint.

- Although fog computing has the advantages of location awareness and low latency, the rising requirements of ubiquitous connectivity and ultra-low latency challenge real-time traffic management for smart cities.

- Integration of fog computing and vehicular networks - vehicular fog computing (VFC) is promising to achieve real-time and location-aware network responses (leverage moving and parked vehicles as fog nodes).

| Features | VCC | VFC |
|---|---|---|
| Individual communication | Bandwidth constrained | Real-time load balancing |
| Burden on core network | High | Low |
| Computational capability | High | Low |
| Deployment cost | High | Low |
| Decision making | Centralized and remote | Distributed and local |
| Resource optimization | Global | Local |
| Latency | High | Low |
| Mobility management | Easy | Hard |
| Reliability | High | Low |

| Features | Vehicular Edge Computing | Vehicular Cloud Computing |
|---|---|---|
| Location | At user's proximity | Remote location |
| Latency | Low | High |
| Mobility support | High | Limited |
| Decision making | Local | Remote |
| Communication | Real Time | Constraints in Bandwidth |
| Storage Capacity | Limited | Highly Scalable |
| Context awareness | Yes | No |
| Device Heterogeneity | Highly Supported | Limited Supported |
| Computing Capability | Medium | High |
| Cost of Development | Low | High |


Cloud
Cloud Data Center
Cloud Storage
Cloud Gateway
Fog-Cloud Interface
Cloudlet
Fog-Fog Interface
Fog-Vehicle Interface
Vehicle/End Devices
Vehicle Cluster
Vehicle Cluster

- ***Cloud Layer:*** It is generally constituted by a traffic management server (TMS) and a trusted third authority (TTA). It performs city-level monitoring and centralized remote control.
- Generally, TMS is in charge of processing messages and informing traffic managers to take actions. If all the messages uploaded by vehicles are processed at the TMS side, it would be overloaded - TMS can be merely in charge of result reception and reward allocation. Individual rewards and network fairness can be managed by TTA.

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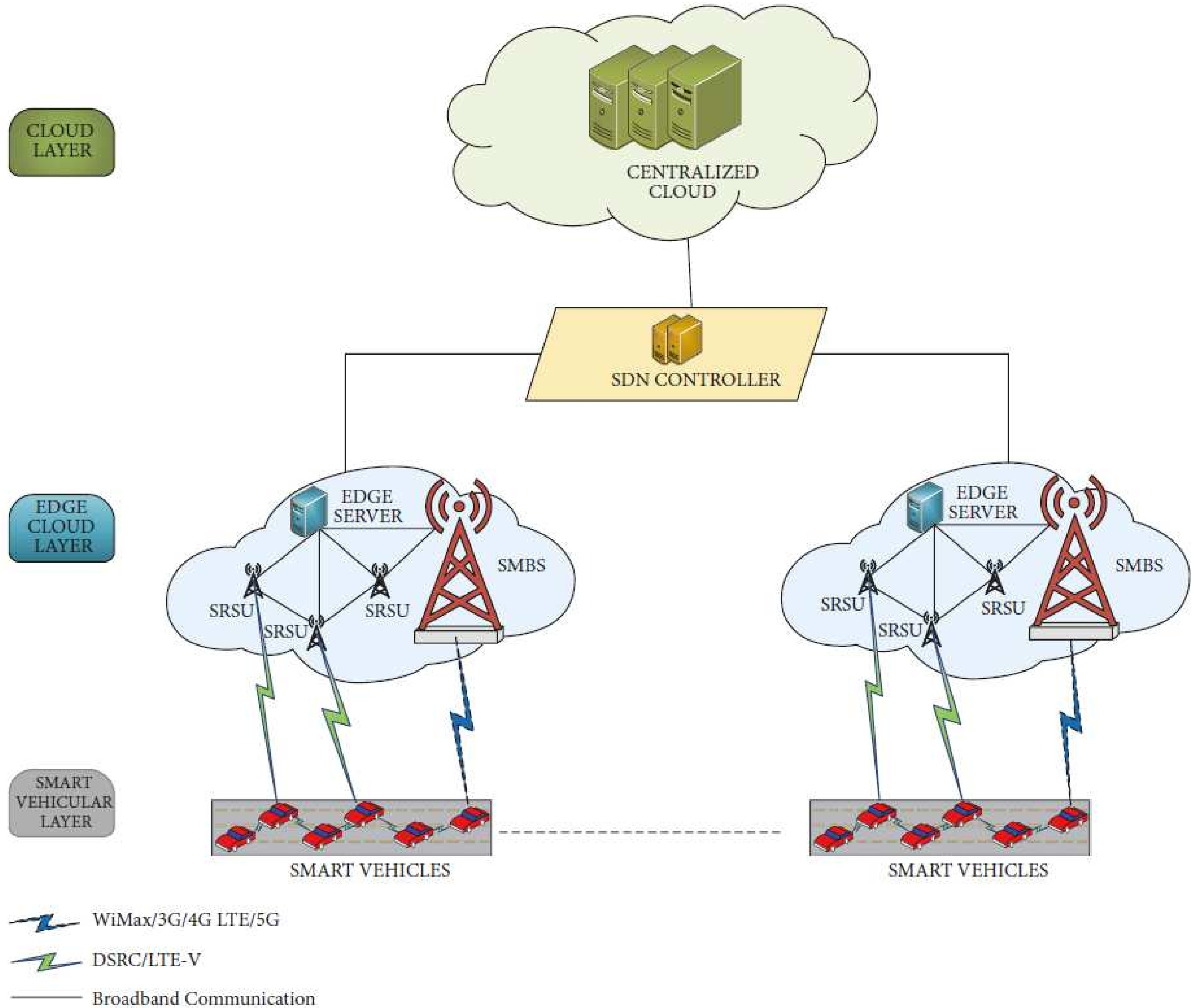
- ***Cloudlet Layer:*** It receives data reported by vehicles, and processes collected data before delivering them to cloud layer.
- Since contents generated by vehicles are always of local interest, the uploaded information related to road conditions merely interests vehicles inside or around a specific region.
- Hence, a city is separated into different regions - in the center of each region, a cloudlet is responsible for management of uploaded messages by vehicles.
- This layer includes various network devices including gateway, routers, and access points. Some RSUs may also exist to schedule message uploading and manage the messages generated by vehicles.

- ***Fog Layer:*** It consists of vehicles/devices in the wireless communication range of RSUs.
- This layer is significant for VFC due to the growing sensing, computing, communication, and storage abilities of vehicles/onboard equipment.
- Some data generated by vehicles can be utilized for vehicle-level network decision making, and others can be uploaded to the fog layer for processing. Both parked and moving vehicles near RSUs can be used to form fog nodes for VFC, and information of sensed events can be uploaded to RSUs.
- After that, RSUs decide whether the uploaded traffic is handled by the cloudlet or fog nodes.
- Within one region, a cloudlet, a group of RSUs, and a collection of vehicle-based fog nodes coexist.


CLOUD LAYER
CENTRALIZED CLOUD
SDN CONTROLLER
EDGE CLOUD LAYER
EDGE SERVER
SMBS
SRSU
SRSU
SRSU
EDGE SERVER
SMBS
SRSU
SRSU
SRSU
SMART VEHICULAR LAYER
SMART VEHICLES
SMART VEHICLES
WiMax/3G/4G LTE/5G
DSRC/LTE-V
Broadband Communication

- **Cloud Layer**

- Most important advantages of cloud layer are data aggregation, data mining, analysis optimization, storage, batch processing, and computation of complex data which are beyond the computation power of the edge nodes.

- Cloud infrastructure comprises two parts, storage and computation.

- Data collected through different edge nodes, which could be used for a later/longer period and need not real-time computation, will be sent to cloud layer through SDN controller, where it is permanently stored for future analysis.

- Complex computational tasks, which are not latency-sensitive, are sent to cloud through edge nodes.

- **Edge Cloud Layer**

- It ensures connection between the smart vehicular layer and cloud layer. For achieving this, vehicles contain devices that make use of wireless communication protocols such as 802.11p, 3GPP, 3G, 4G, LTE, and 5G.

- The purpose is to provide low latency, location awareness, emergency management, caching, content discovery, and computation and improves quality of services since it is at the proximity to vehicles, and it is used for real-time interaction.

- Edge cloud layer also deals with those applications, which need a quick response with very low latency, that is, AR, environment recognition, video analytics, health recognition, and human behavior recognition, and so forth.

- This layer also provides a communication facility for vehicles to vehicles (V2V) and with an external infrastructure vehicle to Infrastructure (V2I).

- In V2V, vehicles interact with each other which are in the same range of communication, so information can be propagated through vehicles until it arrives on the edge.
- For instance, if any vehicle exhibits strange behavior, in case of direction change, violation of the speed limit, or mechanical failure, emergency messages will be sent to neighboring vehicles as well as to edge, which contain the position, speed, and moving direction of that specific vehicle.

- The V2I is liable for exchange of operational data among vehicles through infrastructures like roadside units, micro base stations, and edge servers over wireless networks. This layer comprises many components and all are being managed through SDN.

- *SDN-Supported Components*: A key requirement of VEC is the management of a high number of vehicles and their intermittent connections - SDN.

- (i) SC: SDN controller is the overall central intelligence point of the network. It governs the entire behaviors of the network. It also acts as edge orchestration and resources management for the edge.

- (ii) SES: SDN-based edge server, a group of SRSUs is connected to an edge server over broadband connections. SES provides the vehicles storage and computational facility at the edge of the network. It also stores regional road system information and performs emergency services.

- (iii) SMBS: SDN micro based station is not only capable of carrying voice data, but it is also more sophisticated. SMBSworks under the supervision of the SC, running OpenFlow, and capable of delivering edge services. SMBS is also local intelligence edge device.

- (iv) SRSU: SDN-based roadside unit, running OpenFlow and managed by the SC. It is an edge device. It can exchange data with those vehicles that are in its communication range.

- (v) SSV: SDN-based smart vehicle acts as a forwarding device (end user), armed with On-Board Unit (OBU) and operating OpenFlow. It can communicate with other vehicles, SRSU, and SMBS. It is also considered as Data Plane element.

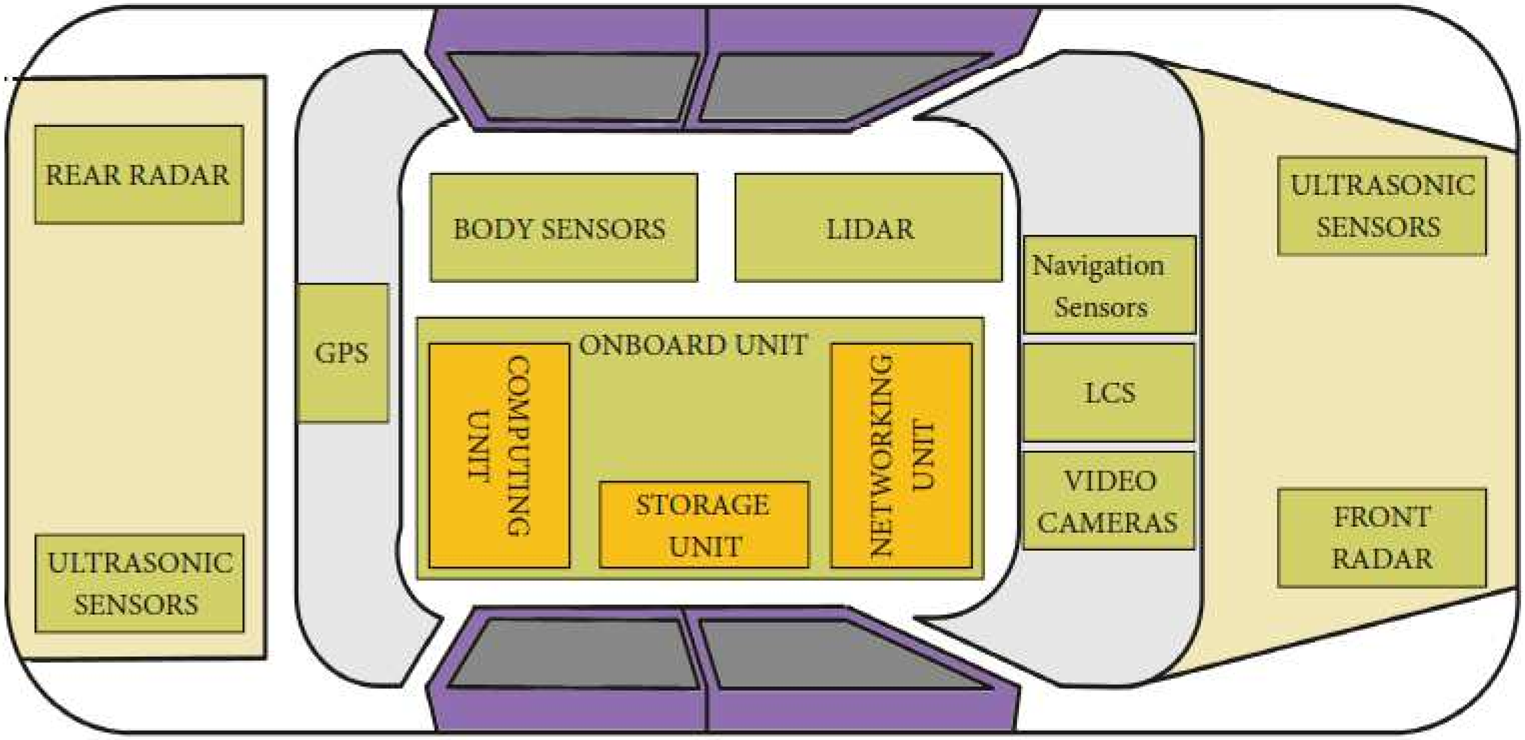
- **Smart Vehicular Layer**

- Vehicles are likely to perform more communication, exchange onboard services, and offer storage. The smart vehicular layer contains a group of vehicles that are geographically close and share computing and storage resources through the wireless network.

- Smart vehicular layer is responsible for abstracting information from embedded sensors, GPS, camera, radar, lidar, and other devices that vehicles can contain. The collected information can be sent to the edge cloud layer for storage or it serves as input for several services in the application layer.

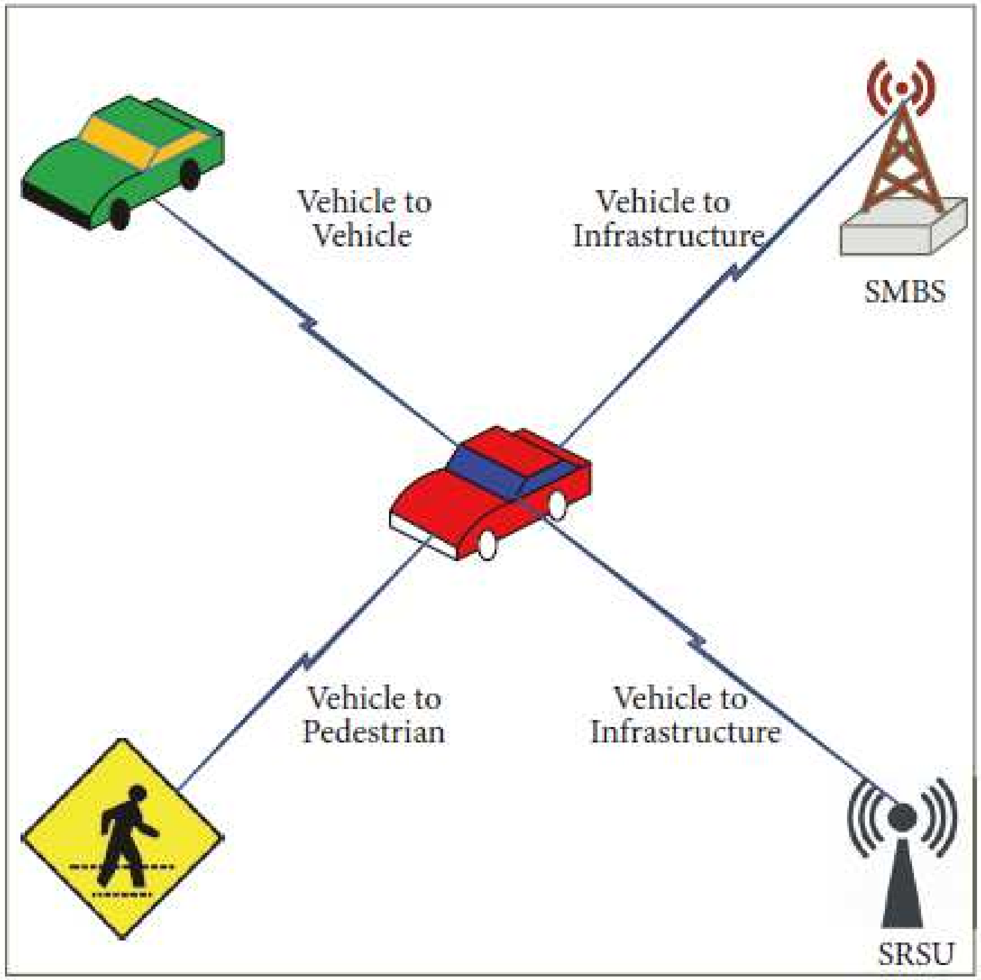
- In smart vehicular layer, the vehicle will have communications, storage, intelligence, and learning capabilities to anticipate the driver's intentions. The idea will help vehicles to use services from other vehicles as smart vehicular computing, offering the computational and offloading facilities for vehicles available at the edge of the network and providing all the services required by the autonomous vehicles.

# Smart vehicle




CPU, Wireless transceiver, GPS receiver, Sensors, I/O interface, RADAR
LIDAR: Light Detection and Ranging
LCS: Local Camera Sensor

# Communication of Smart Vehicle



# Vehicle to vehicle and vehicle to infrastructure communication