Intelligent vehicles and autonomous driving

PERCEPTION SYSTEMS 2022 / 2023

Lesson 2

Alice Plebe
University of Trento

RECAP

- Autonomous driving task = perception + action
- Perception = collect info + process info
- Info on ego/scene comes from sensors + HD maps
- Proprioceptive sensors (ego) = GNSS, IMU, odometry
- Exteroceptive sensors (scene) = sonar, radar, lidar, camera
- Many possible combinations of sensor setup

HD MAPS

HIGH DEFINITION MAPS

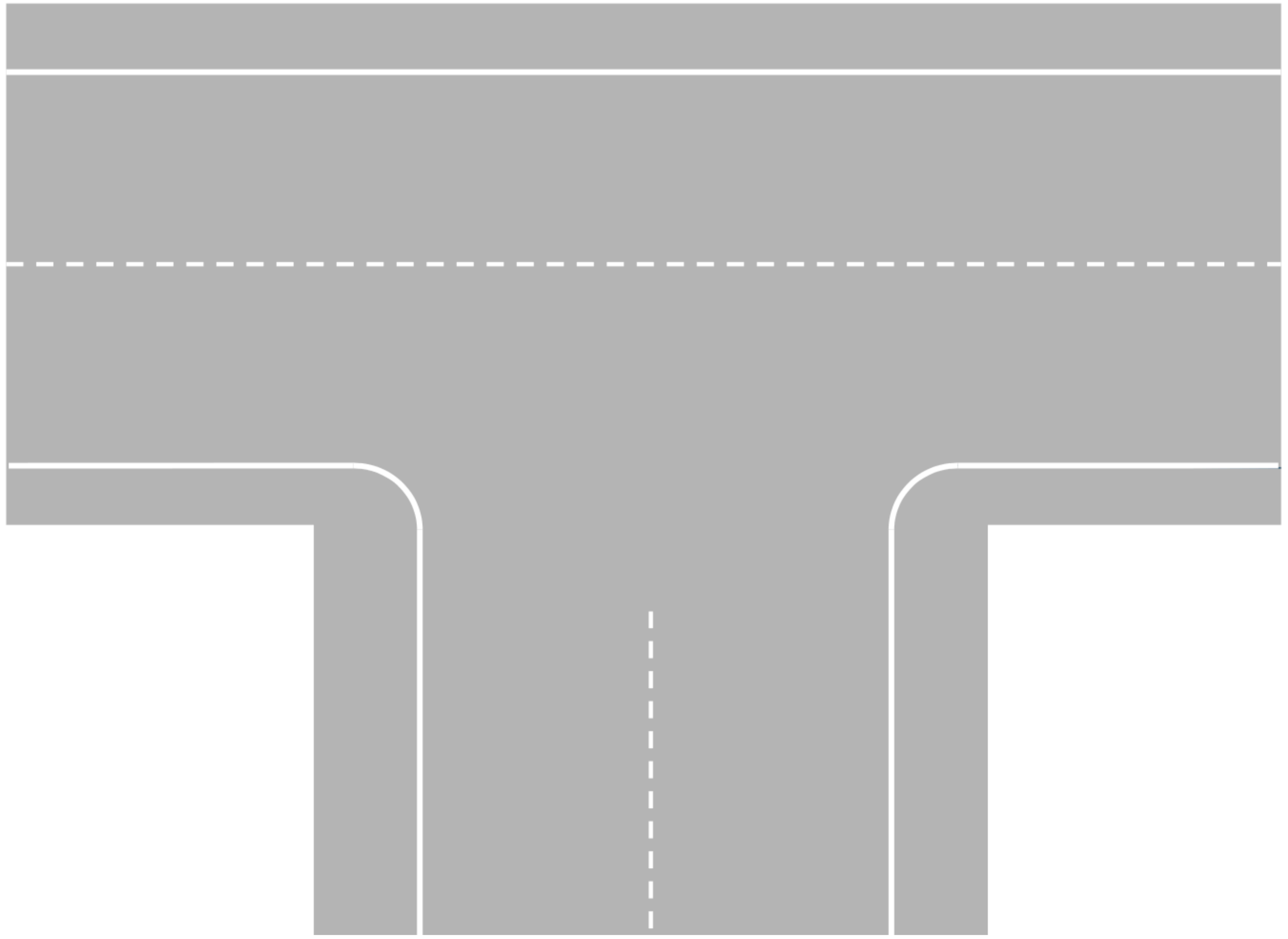
Provide 3D information about environment to simplify perception.

Different from standard digital navigation maps. HD maps have high accuracy (~10cm) and are specifically design for AV.

MAP LAYERS

- GEOMETRIC
- SEMANTIC
- ROAD NETWORK
- EXPERIENTIAL
- REAL TIME

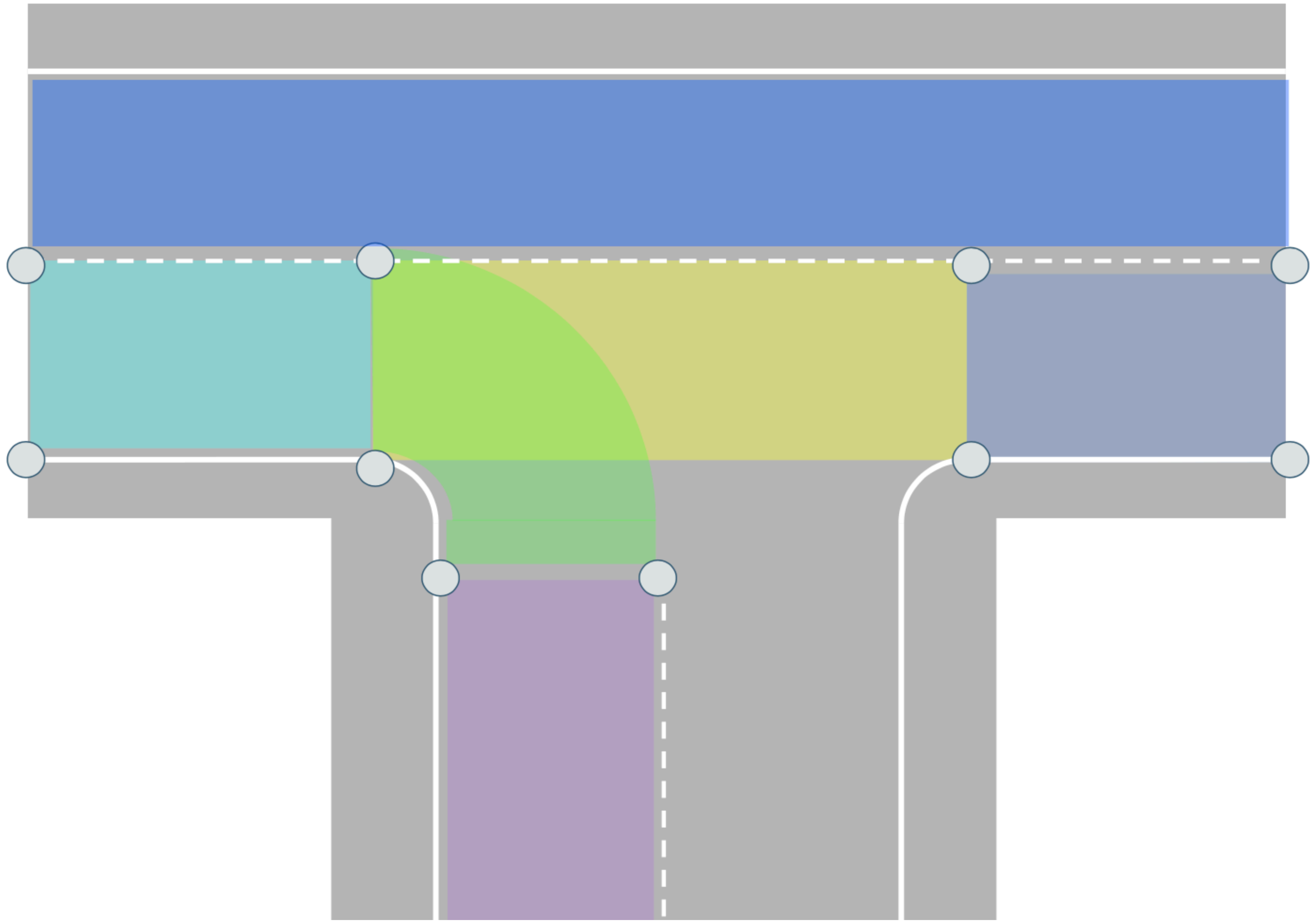
Organized into layers depending on the abstraction of the information.



GEOMETRIC LAYER

- GEOMETRIC
- SEMANTIC
- ROAD NETWORK
- EXPERIENTIAL
- REAL TIME

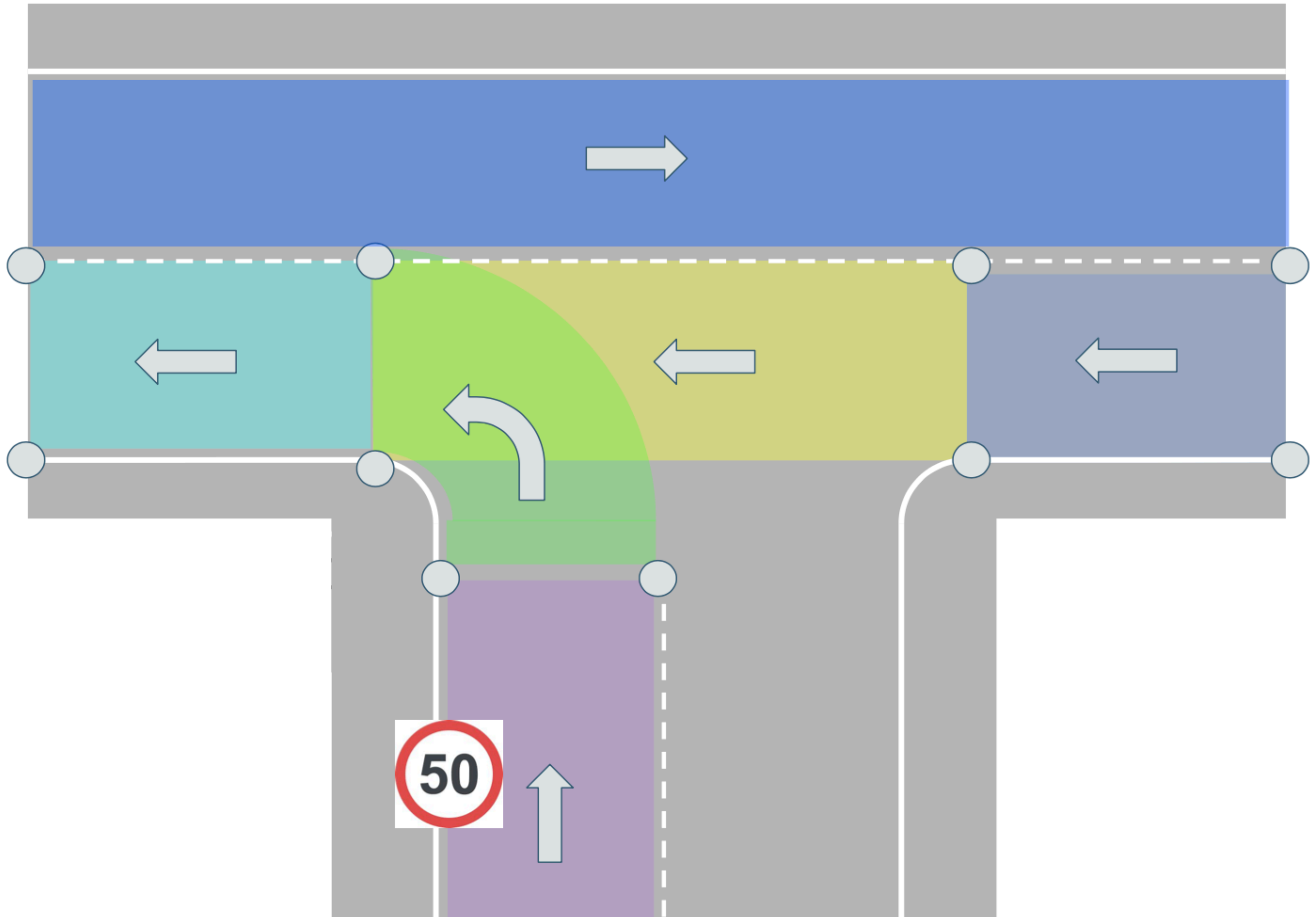
Physical positions of roads and objects. Described by geometric primitives (points, curves, polygons).



SEMANTIC LAYER

- GEOMETRIC
- SEMANTIC
- ROAD NETWORK
- EXPERIENTIAL
- REAL TIME

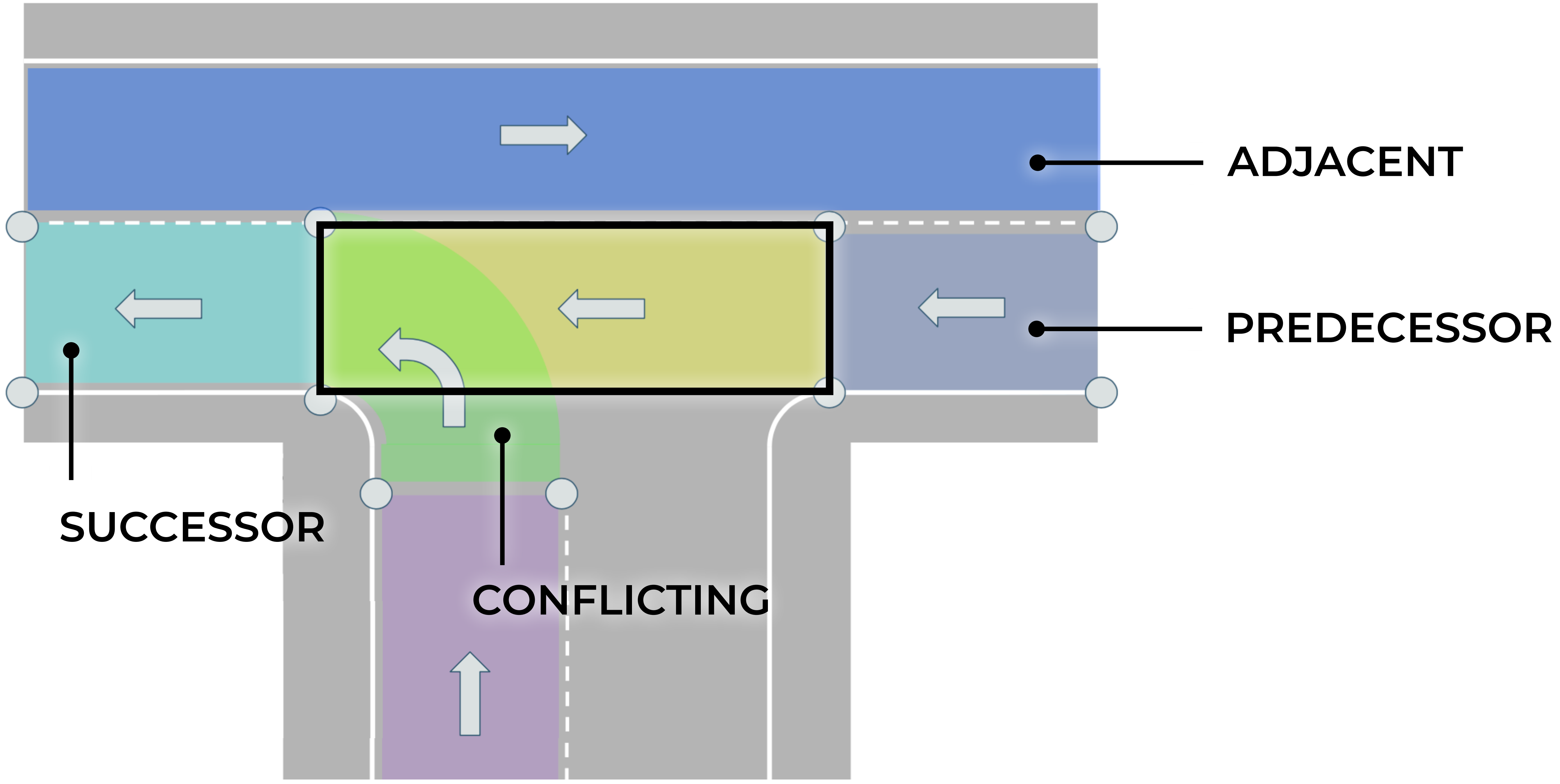
Attach semantic meaning to geometric primitives.
Includes travel direction of each lane, speed limit.



ROAD NETWORK LAYER

- GEOMETRIC
- SEMANTIC
- **ROAD NETWORK**
- EXPERIENTIAL
- REAL TIME

Describes the connectivity between lane primitives (successor, predecessor, adjacent, conflicting lanes).



EXPERIENTIAL LAYER *(MAP PRIOR)*

- GEOMETRIC
- SEMANTIC
- ROAD NETWORK
- **EXPERIENTIAL**
- REAL TIME

Information like expected traffic flow in a given lane, or historic incidence of accidents in an intersection.

To improve travel time or fuel consumption.

Updated periodically from the aggregated past experience of a dedicated fleet of vehicles.

REAL TIME LAYER

- GEOMETRIC
- SEMANTIC
- ROAD NETWORK
- EXPERIENTIAL
- **REAL TIME**

Dynamic changes in the map like locations of traffic jams, accidents, road maintenance.

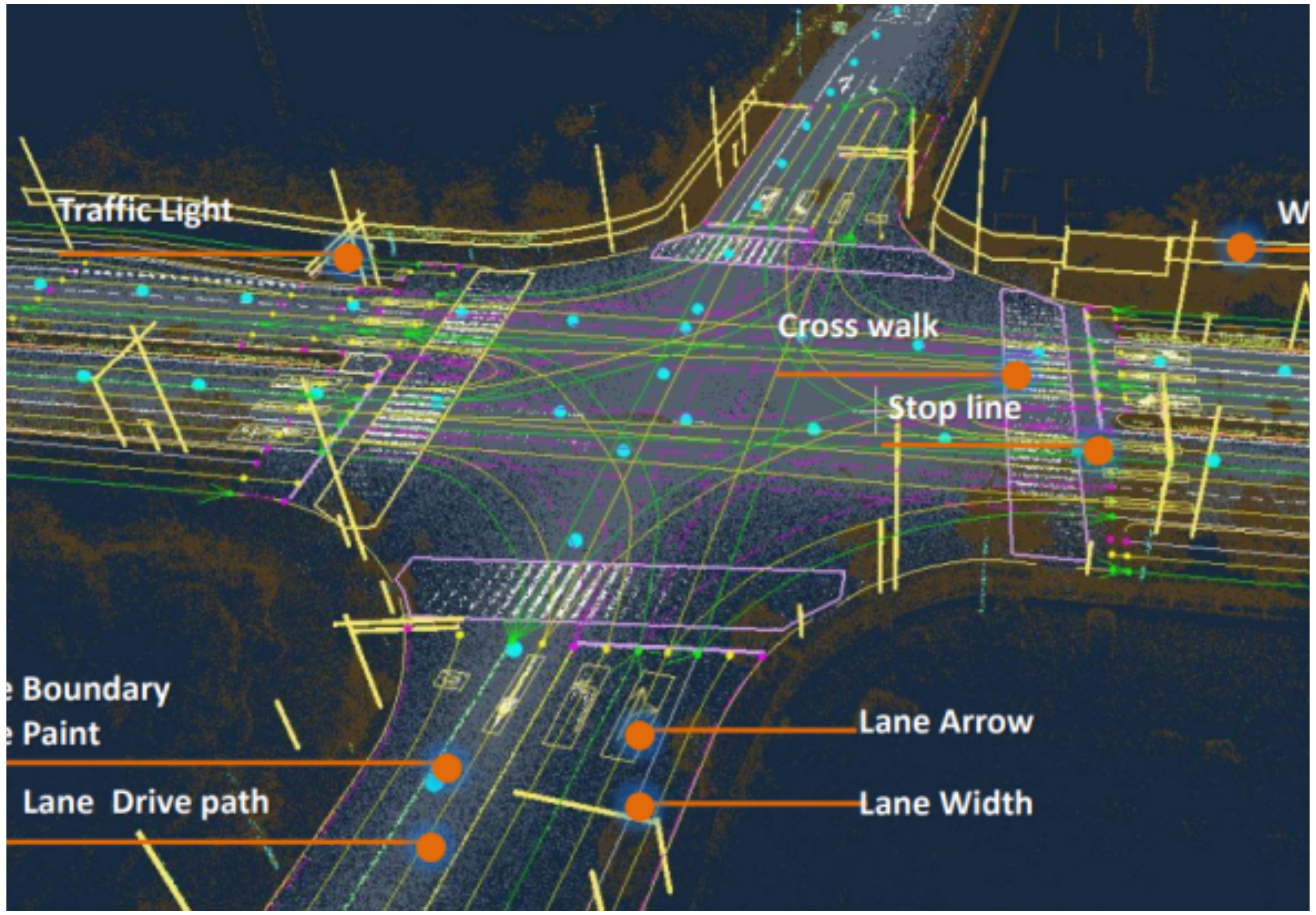
To improve route planning but also to change the road geometry (construction zones, stalled vehicles).

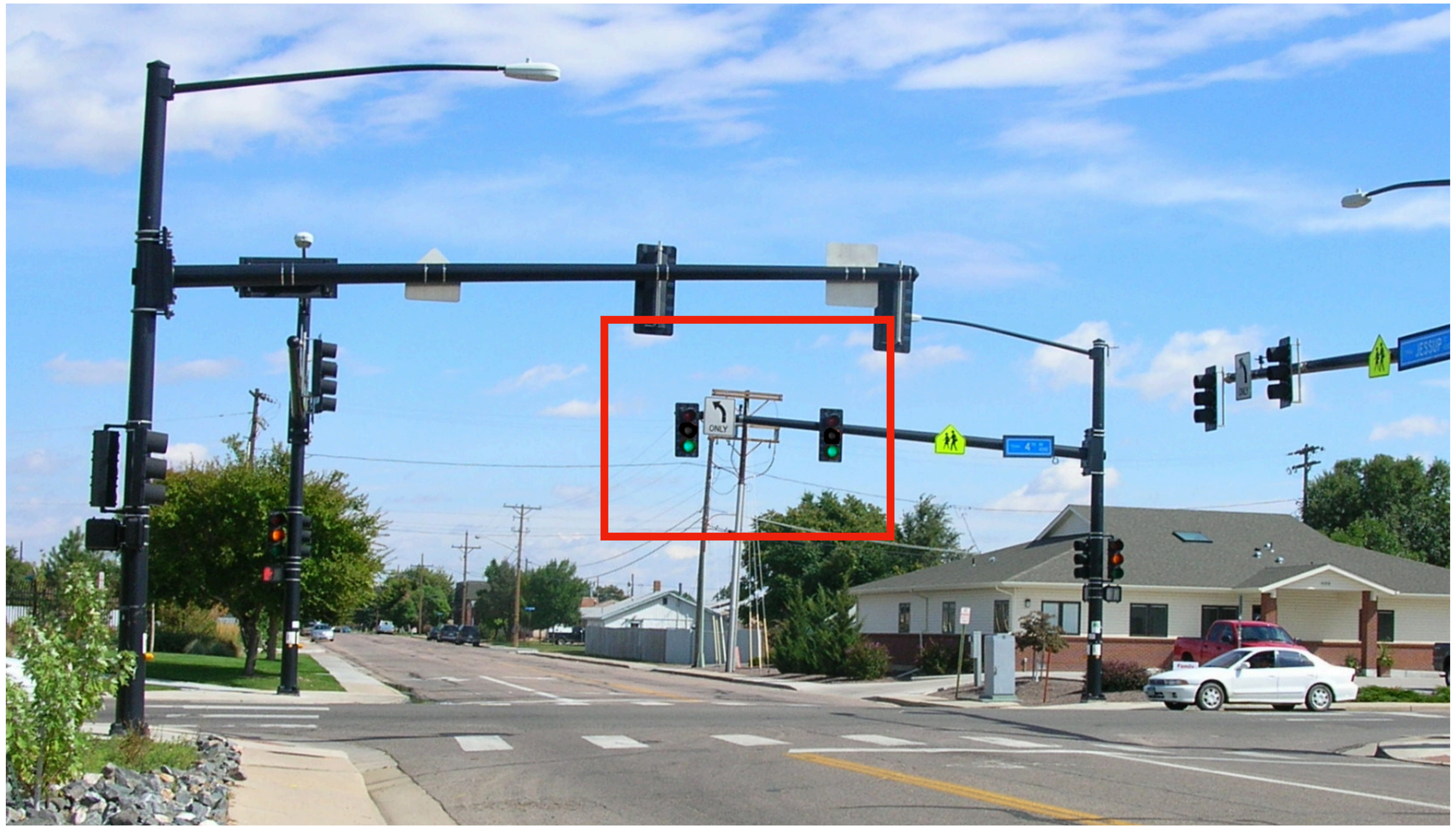
Updated in real time from surrounding vehicles, road infrastructure, dedicated fleet, regulating authorities.

EXAMPLE OF APPLICATION

No need to detect speed limit signs or types of lane markings.

Also focus perception to critical areas, like traffic lights.





COMMERCIAL PROVIDERS

MAP CREATION

Specific to the map layer.

Geometric layer comes from sensor data collected by fleet of vehicles using LIDAR, cameras, GNSS, odometry.

Semantic layer comes mostly from manual annotation, in combination with satellite images. Very recent attempts to automatic annotation (NVIDIA Drive).

INDUSTRY STANDARDS

Navigation Data Standard (NDS) is a proprietary format, the most adopted in the industry. *NDS Open Lane Model* is a reduced open version available for research.

INDUSTRY STANDARDS

Navigation Data Standard (NDS) is a proprietary format, the most adopted in the industry. *NDS Open Lane Model* is a reduced open version available for research.

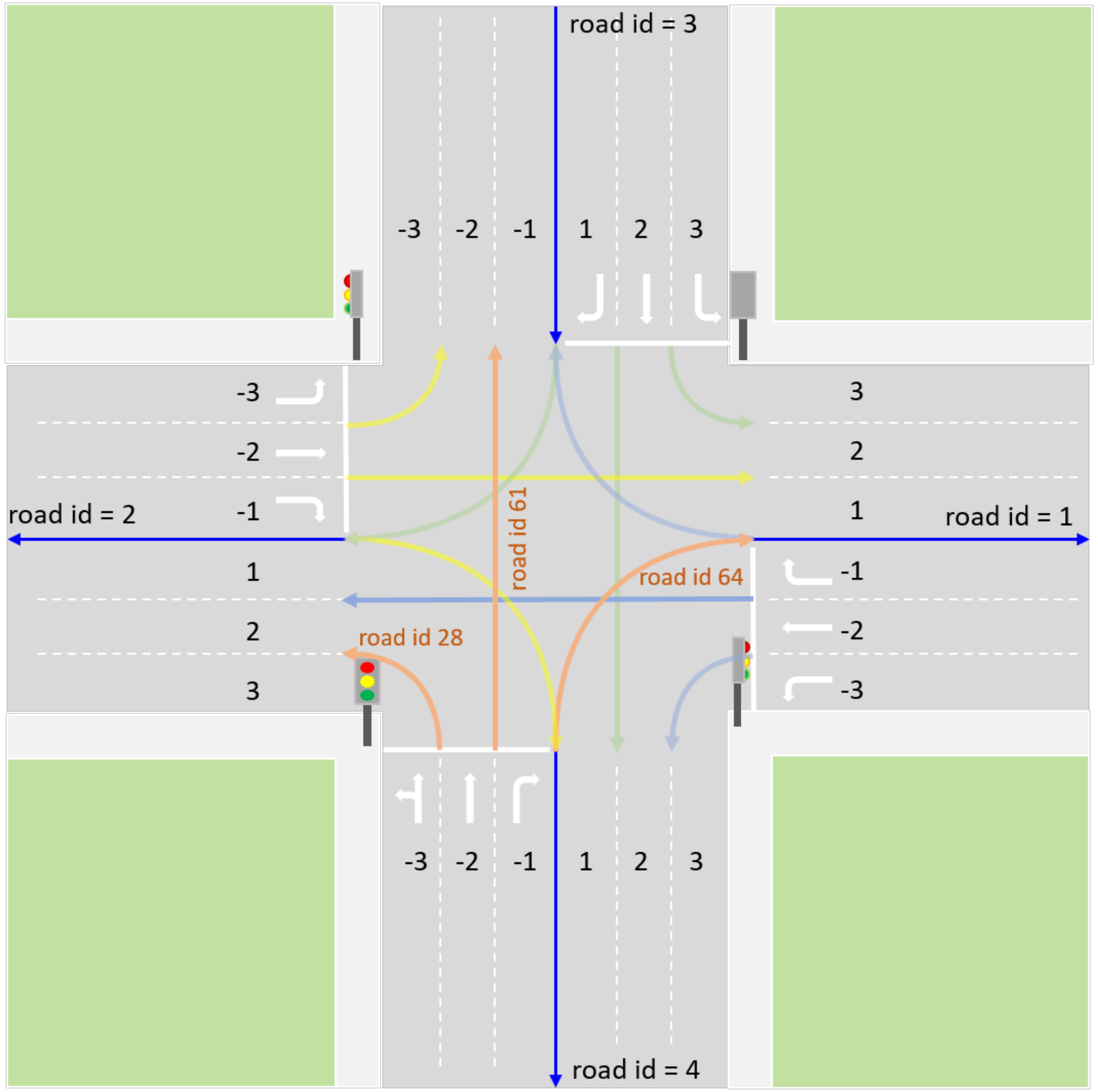
OpenDRIVE is an open format, originally developed for a driving simulator. Maps are stored in a *.xodr* file format written in XML. The road network is modeled along a reference line, and it is composed of individual sections interconnected with each other.

OPENDRIVE

ASAM description
https://www.asam.net/

XODR example files
https://github.com/

Online visualizer
https://odrviewer.io/



SUMMARY

- HD maps contain 3D information about environment with centimeter-level accuracy.
- They simplify perception providing information about position of lanes, pedestrian crossing, traffic signs, traffic lights.
- Organized into five layers: geometric, semantic, road network, experiential, real time.
- Creating HD maps is challenging and done by commercial providers (Lyft, TomTom, HERE).
- Two main industry standards: NDS and OpenDRIVE.

GNSS / IMU

GNSS

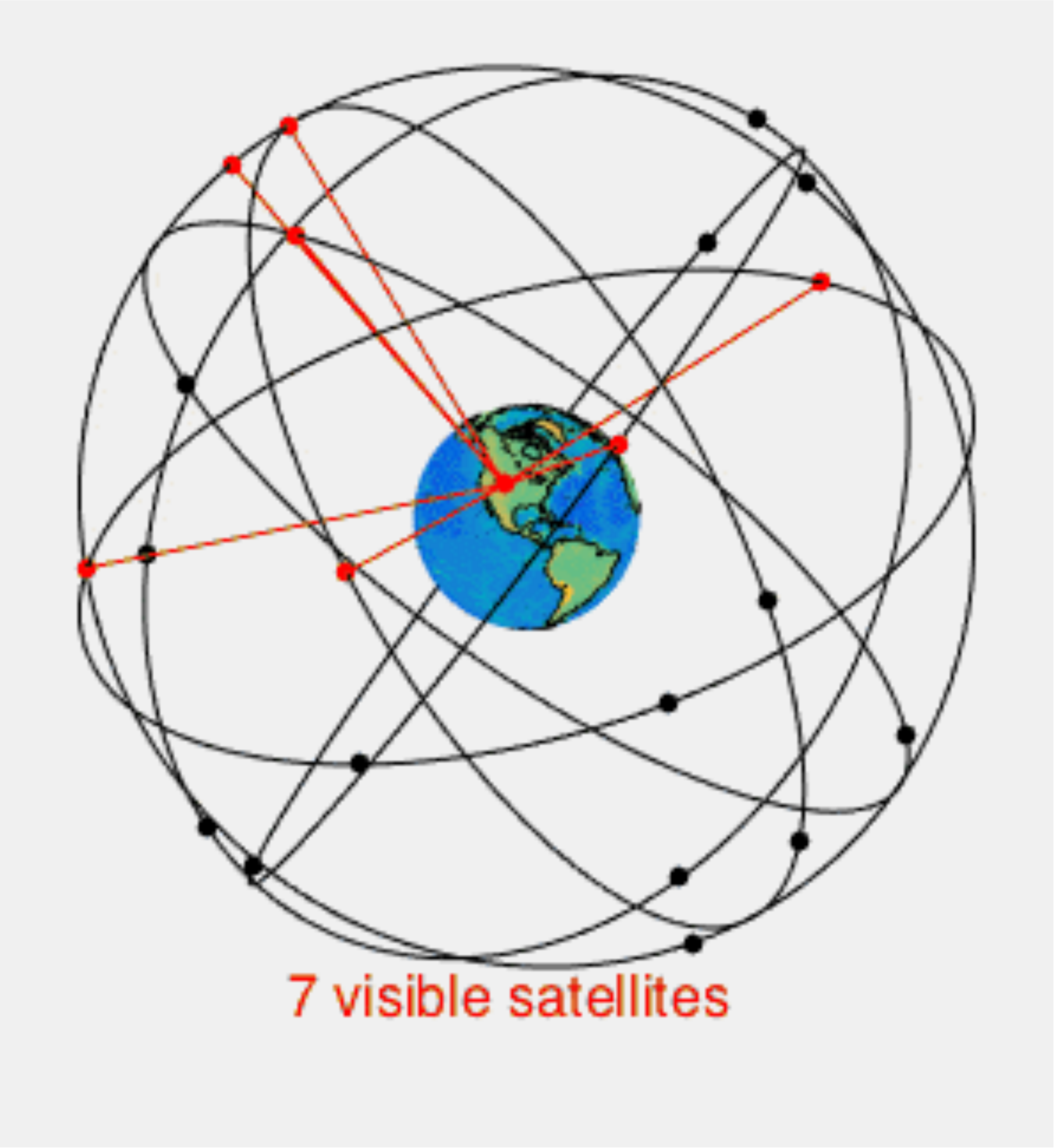
Global Navigation Satellite Systems

First invented for military application in the 1970s.

Examples of GNSS are United State's *global positioning system* (GPS) and European Union's *Galileo*.

GNSS receivers use satellites to determine geo-spatial positioning. They are passive and proprioceptive sensors.

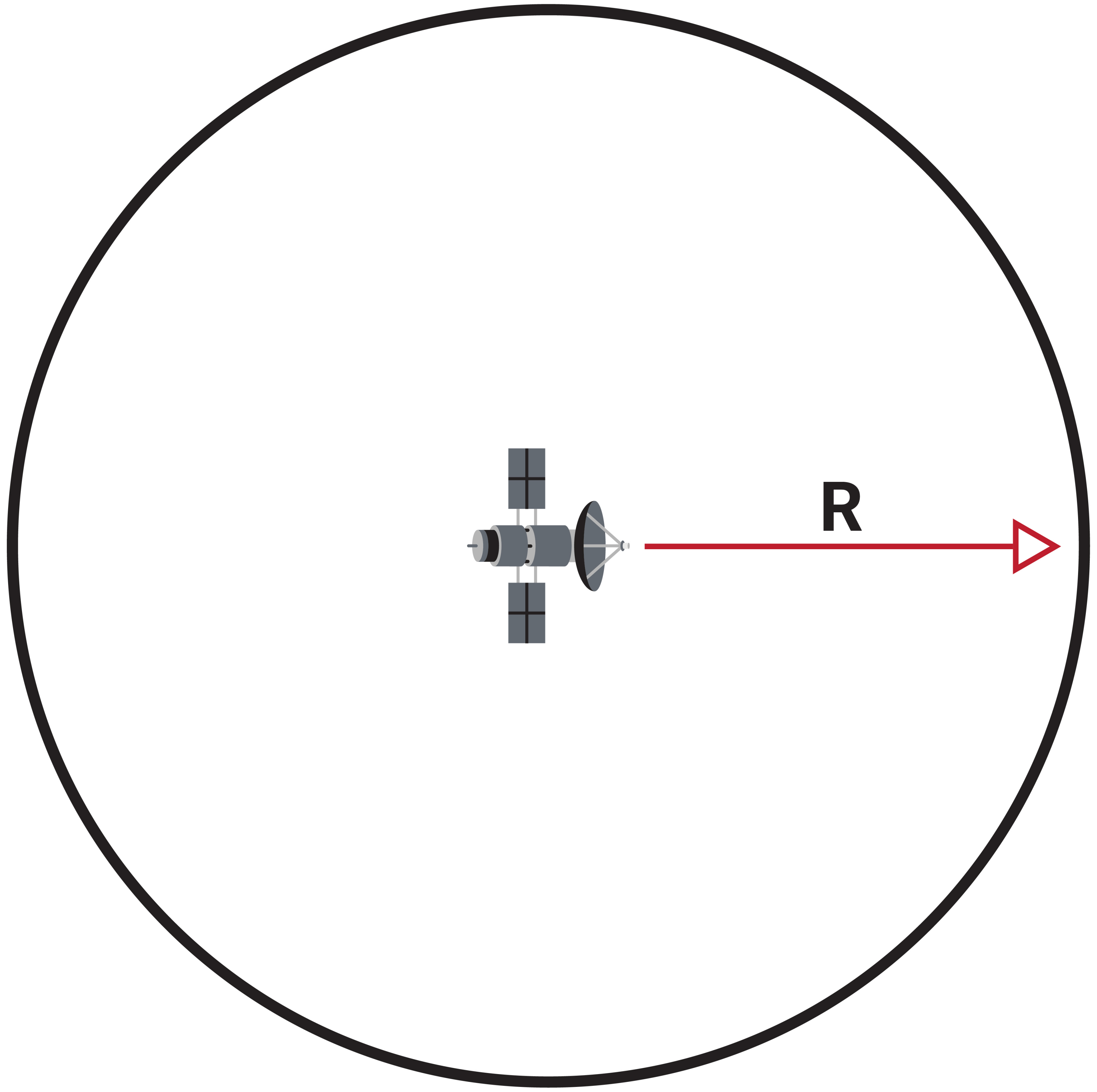
GNSS



The satellites broadcast a signal with their position and time of transmission.

The GNSS receiver compares the transmissions of at least three/four different satellites, measuring the propagation time of each signal.

TRILATERATION

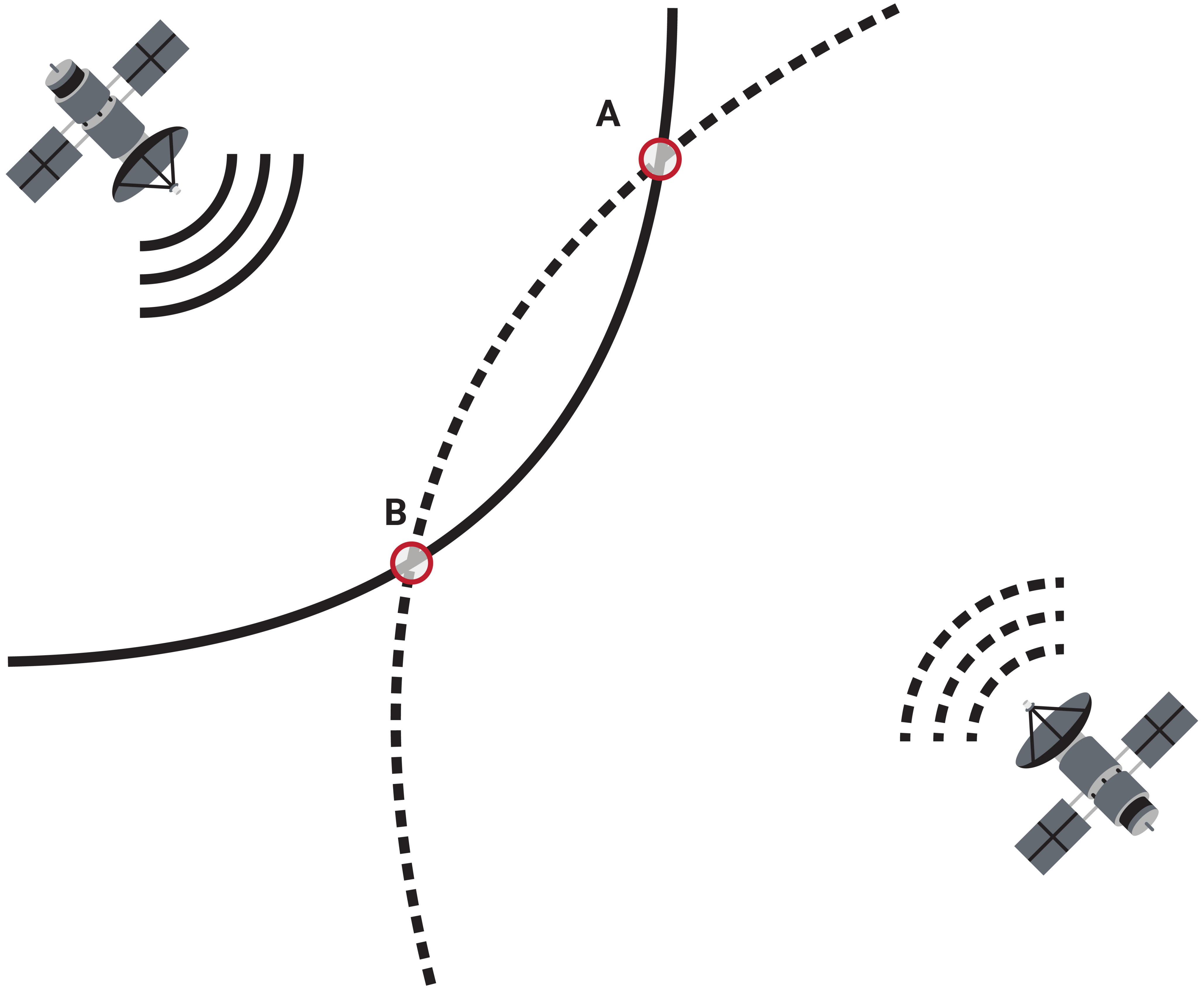


The receiver determines its position (longitude, latitude, altitude) using the principle of trilateration.

Given a satellite, all the possible locations of the receiver lie on the surface of a sphere.

The intersection of three or more spheres from different satellites leads to a single point corresponding to the position of the receiver.

TRILATERATION

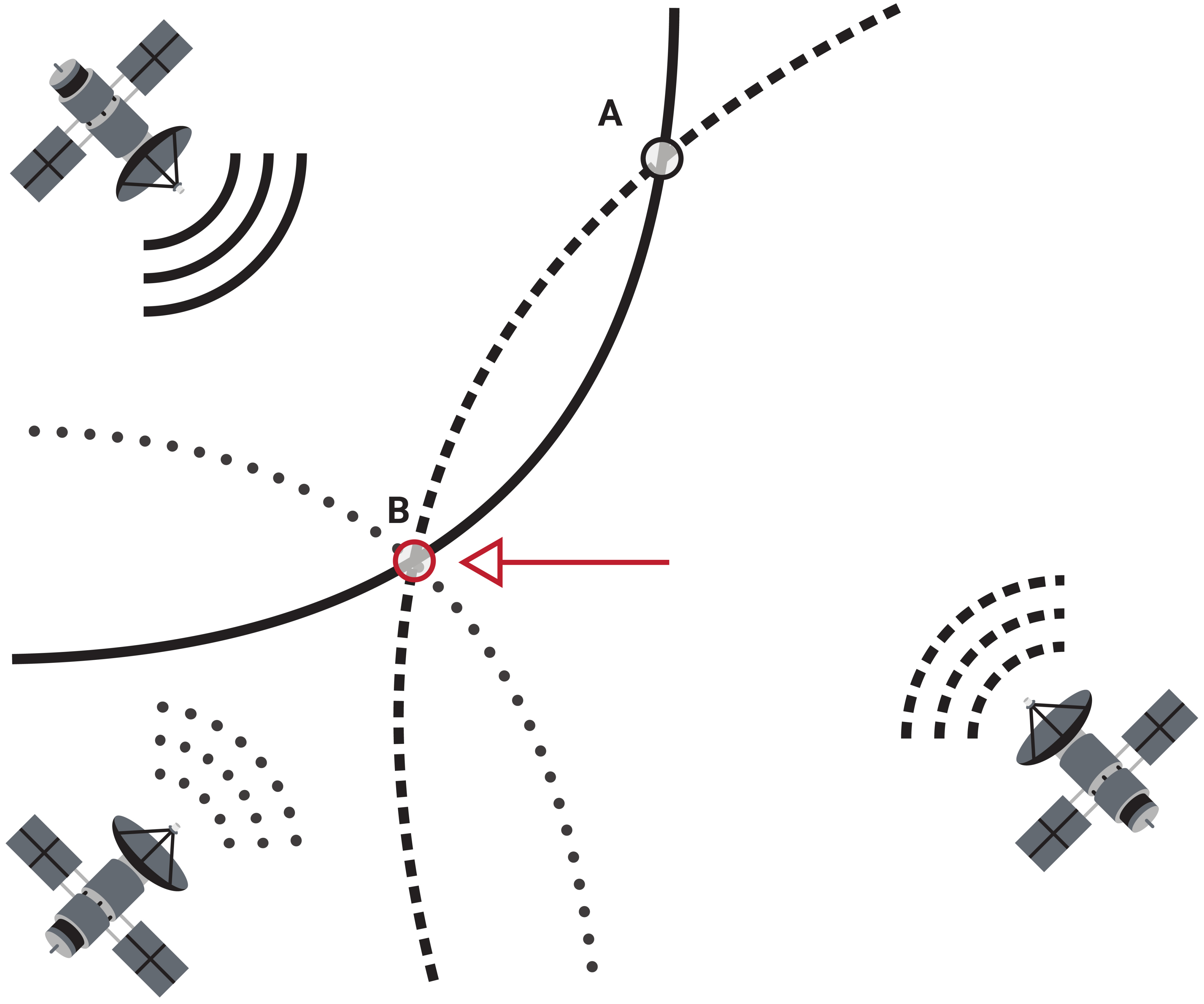


The receiver determines its position (longitude, latitude, altitude) using the principle of trilateration.

Given a satellite, all the possible locations of the receiver lie on the surface of a sphere.

The intersection of three or more spheres from different satellites leads to a single point corresponding to the position of the receiver.

TRILATERATION

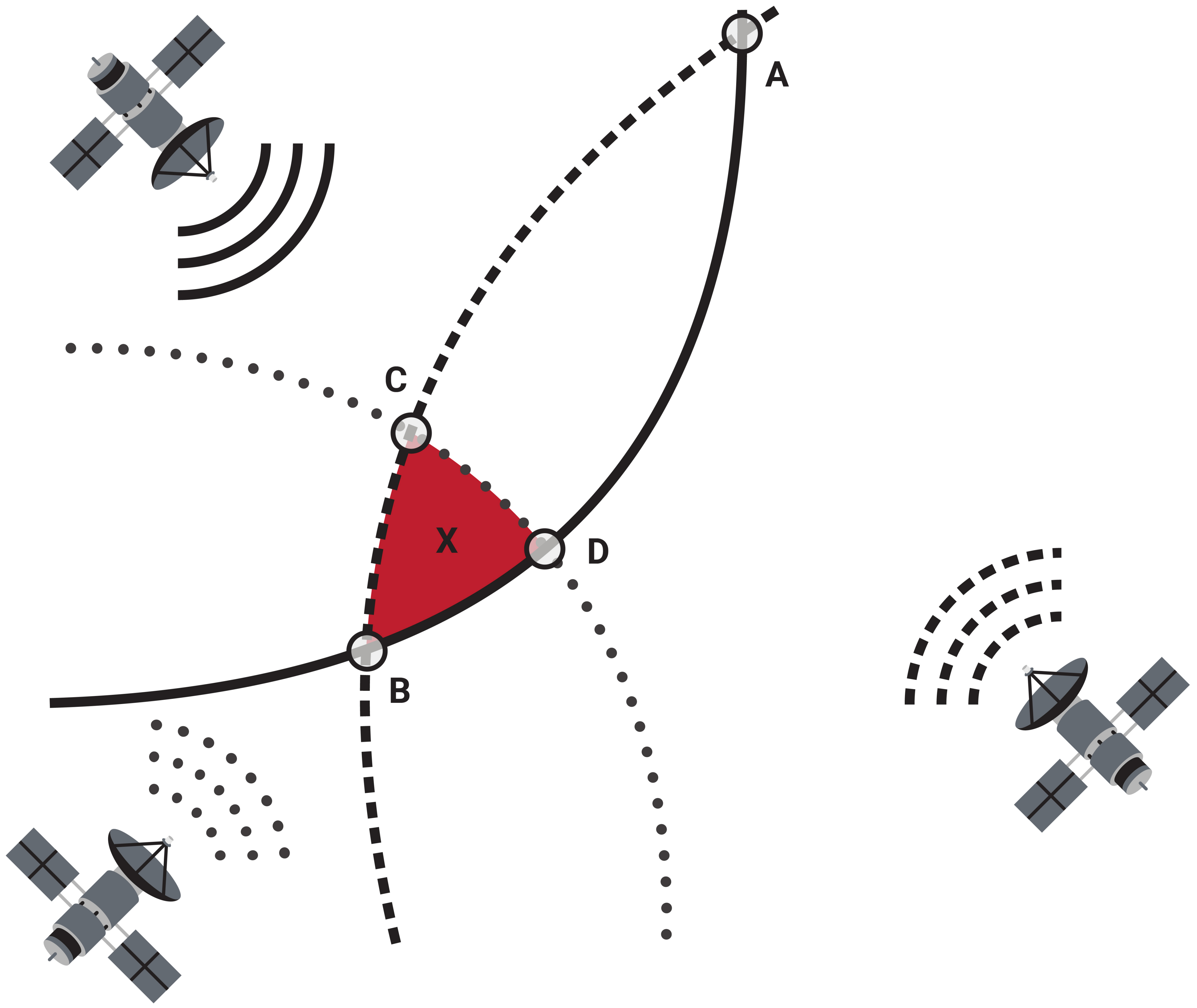


The receiver determines its position (longitude, latitude, altitude) using the principle of trilateration.

Given a satellite, all the possible locations of the receiver lie on the surface of a sphere.

The intersection of three or more spheres from different satellites leads to a single point corresponding to the position of the receiver.

TRILATERATION

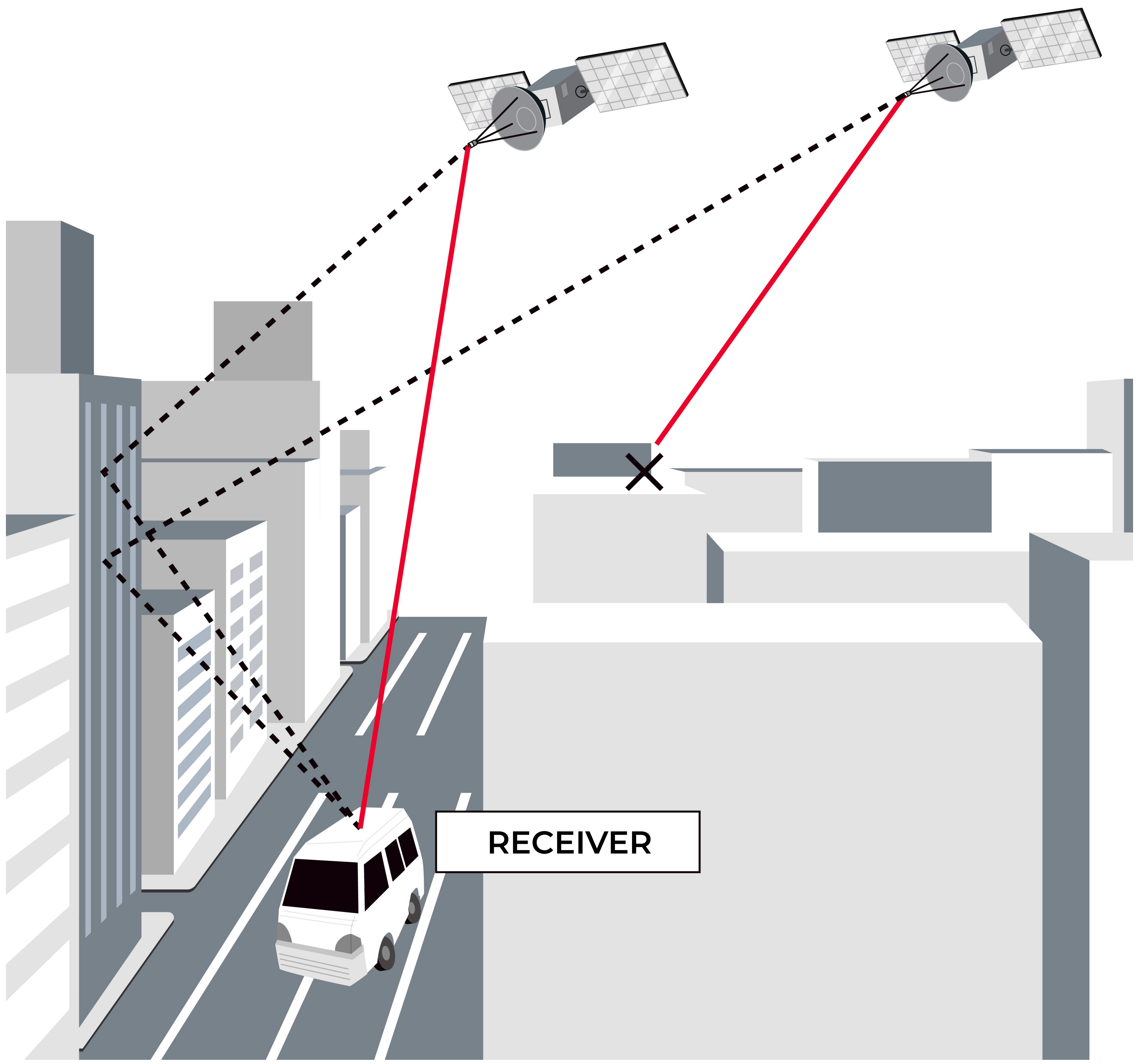


The receiver determines its position (longitude, latitude, altitude) using the principle of trilateration.

Given a satellite, all the possible locations of the receiver lie on the surface of a sphere.

The intersection of three or more spheres from different satellites leads to a single point corresponding to the position of the receiver.

PROS AND CONS



PROS

- cheap and widely available
- do not suffer from accumulated error (unlike IMUs and odometers)

CONS

- does not work in indoor areas (garages, tunnels)
- suffer from multipath propagation in dense urban areas (tall buildings)
- standard accuracy not sufficient for AV applications (~2m)

IMU

*Inertial **M**easurement **U**nit*

Passive sensor that can measure angular rate and orientation, using a combination of accelerometers, gyroscopes, and sometimes magnetometers.

IMUs sense parameters that can be measured under any circumstances (like the Earth's gravitational field and magnetic fields). AV can always rely on getting information from IMUs because they are always available.

ODOMETRY SENSORS

Sensors that measure the distance traveled by a vehicle by multiplying the number of wheel rotations by the tire circumference.

They provide information on current wheel velocity as well as the distance traveled by each wheel.

Anti-lock braking system (ABS) require odometers information to work.

GNSS + IMU + ODOMETER

Measurements from GNSS, IMU, and odometers are normally combined to calculate a vehicle's state obtaining an accurate overall result.