Architecture Requirements for Cyber-Physical Systems

Lotfi ben Othmane

Information Systems

Information systems (IS) are formal, sociotechnical, organizational systems designed to collect, process, store, and distribute information.

"The new automated ordering system has really speeded up our business. We're losing customers faster than ever." 😐

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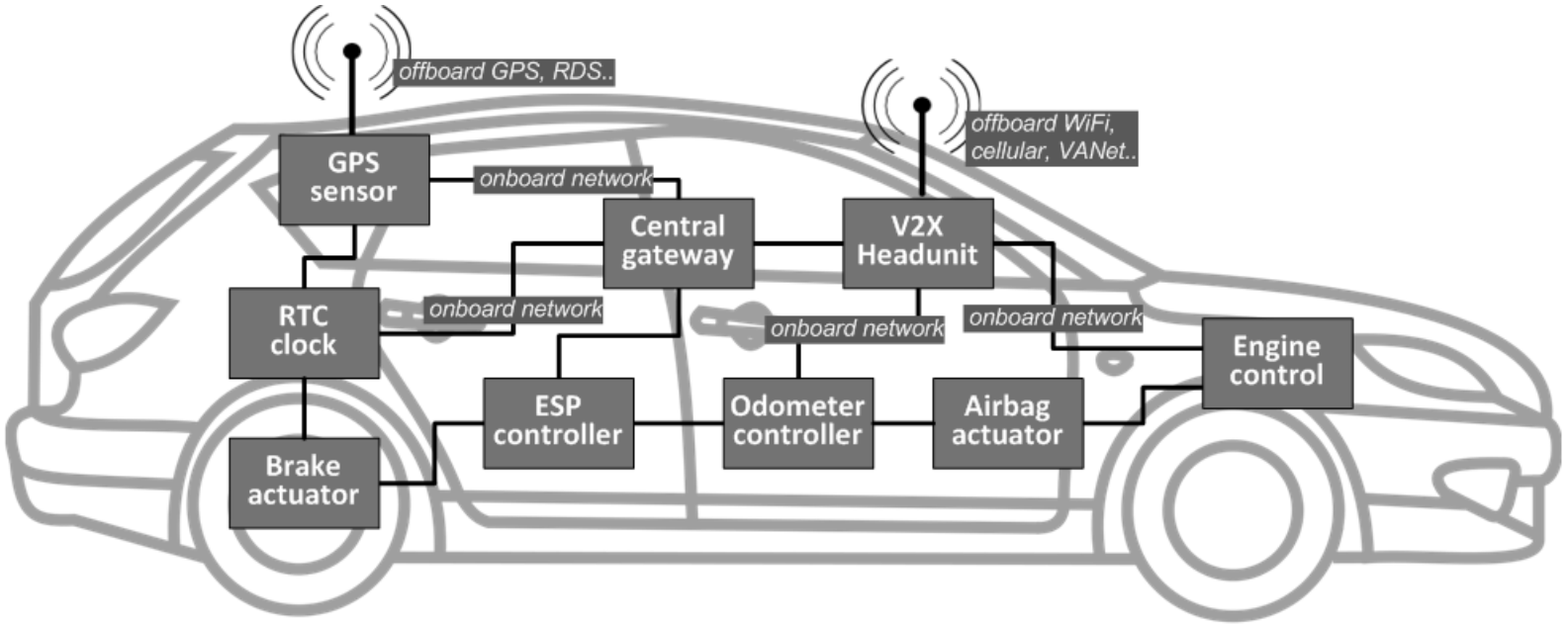
Embedded Systems

An embedded system is a controller programmed and controlled by a real-time operating system (RTOS) with a dedicated function within a larger mechanical or electrical system.

https://en.wikipedia.org

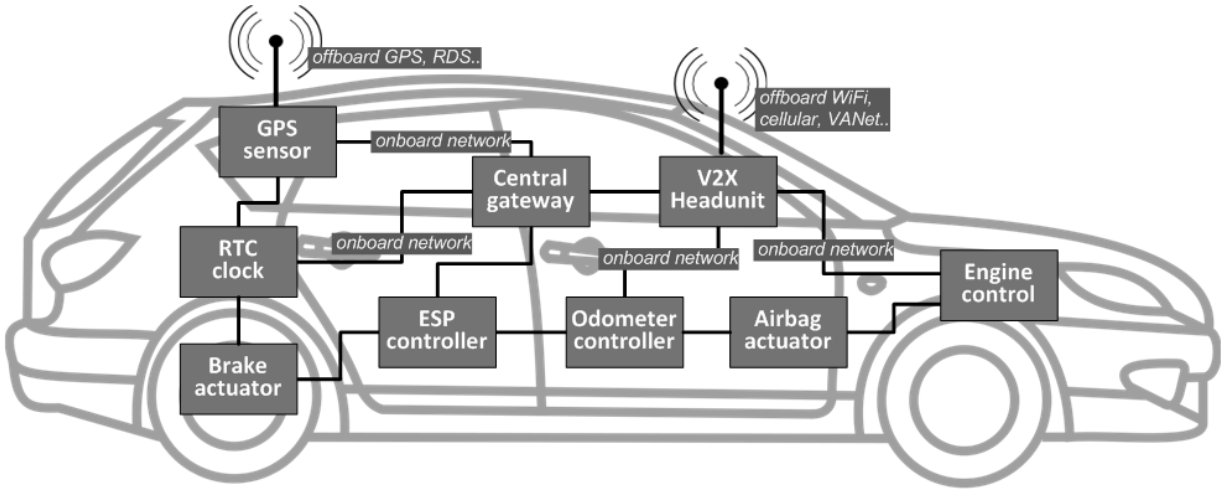


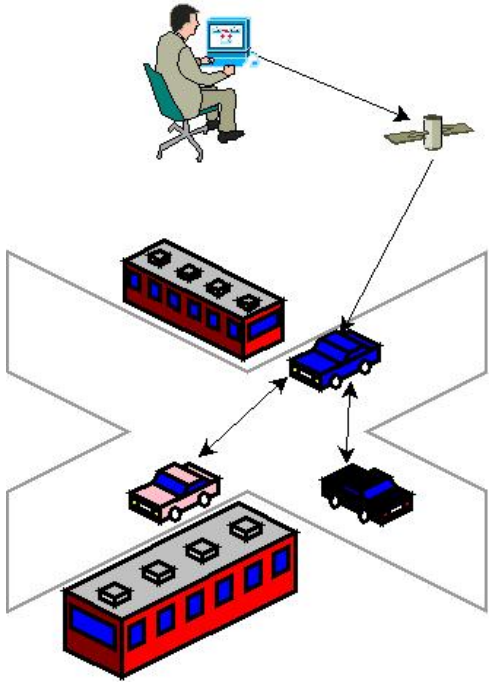
Cyber-physical system

A cyber-physical system is a system that augments the capabilities of physical objects through computation and communication.

(First) The uCAN System

A connected vehicle is a vehicle whose electrical control units communicate through an in-vehicle network, and it communicates with neighboring vehicles, road side units, and service centers through wireless networks.





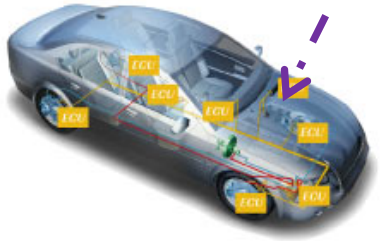
(First) The uCAN System

- The system collects data from the in-vehicle networks of the vehicles and sends them to the cloud provider
- Companies transform the data to services, e.g., fleet management, traffic warning, etc.

Use anonymized data

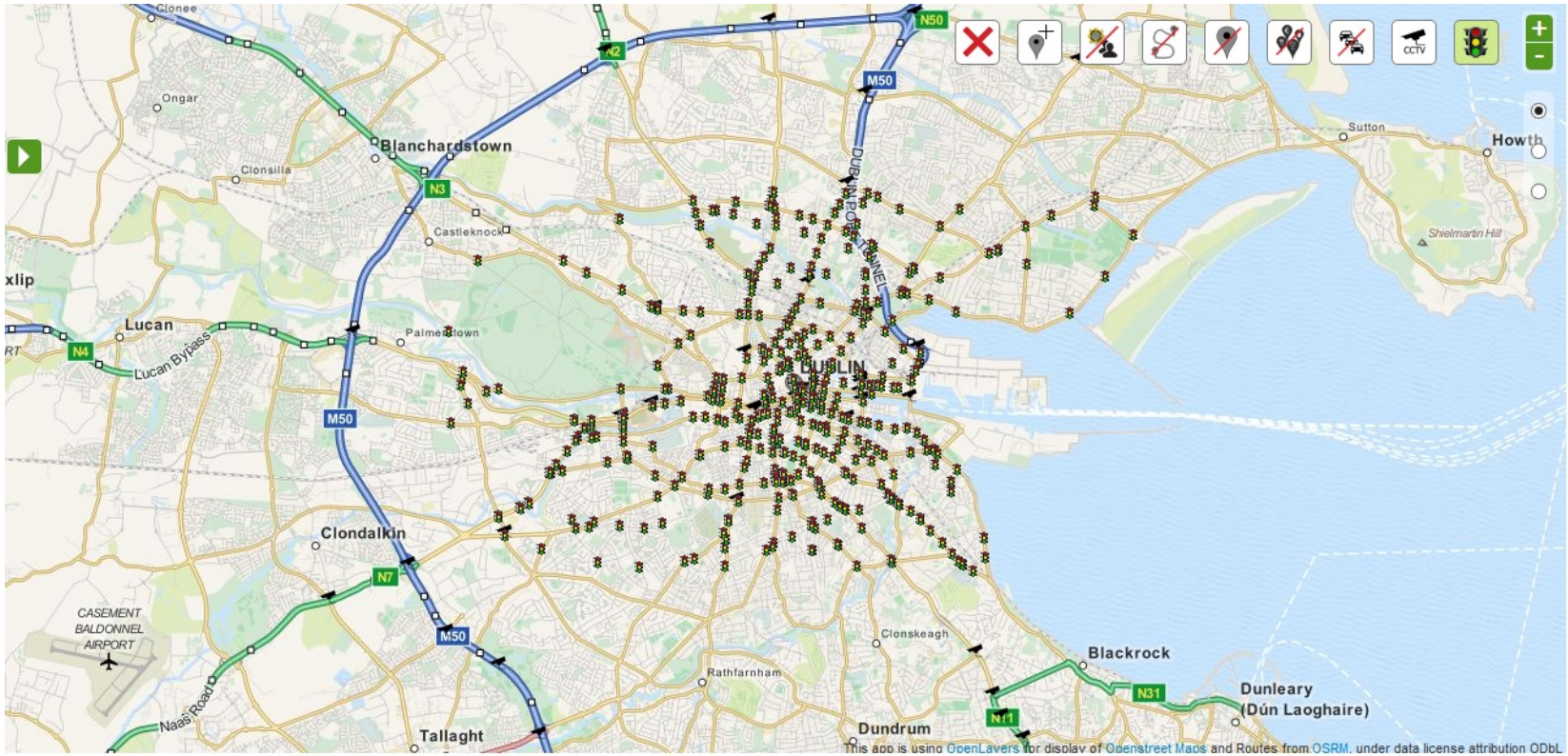
Cloud provider

traffic warning, e-call, etc.



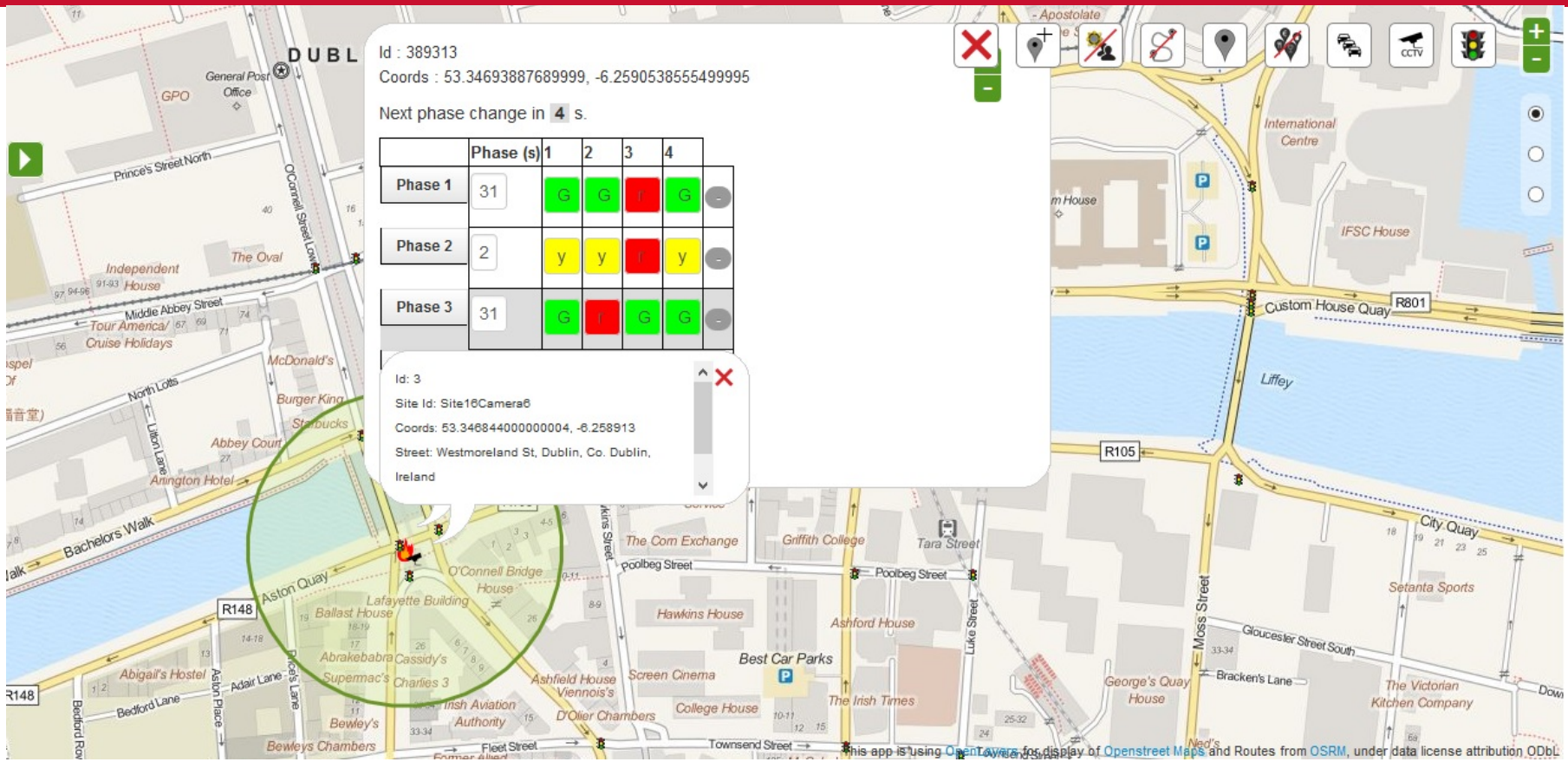
Access to in-car data archive

(Second) Adaptive Security for Smart City



- View from the CarDemo project, being developed by Leo, Ireland, about the traffic lights and cameras in Dublin

(Second) Adaptive Security for Smart City



- Remote access to the traffic lights and to the cameras.

(Second) Adaptive Security for Smart City

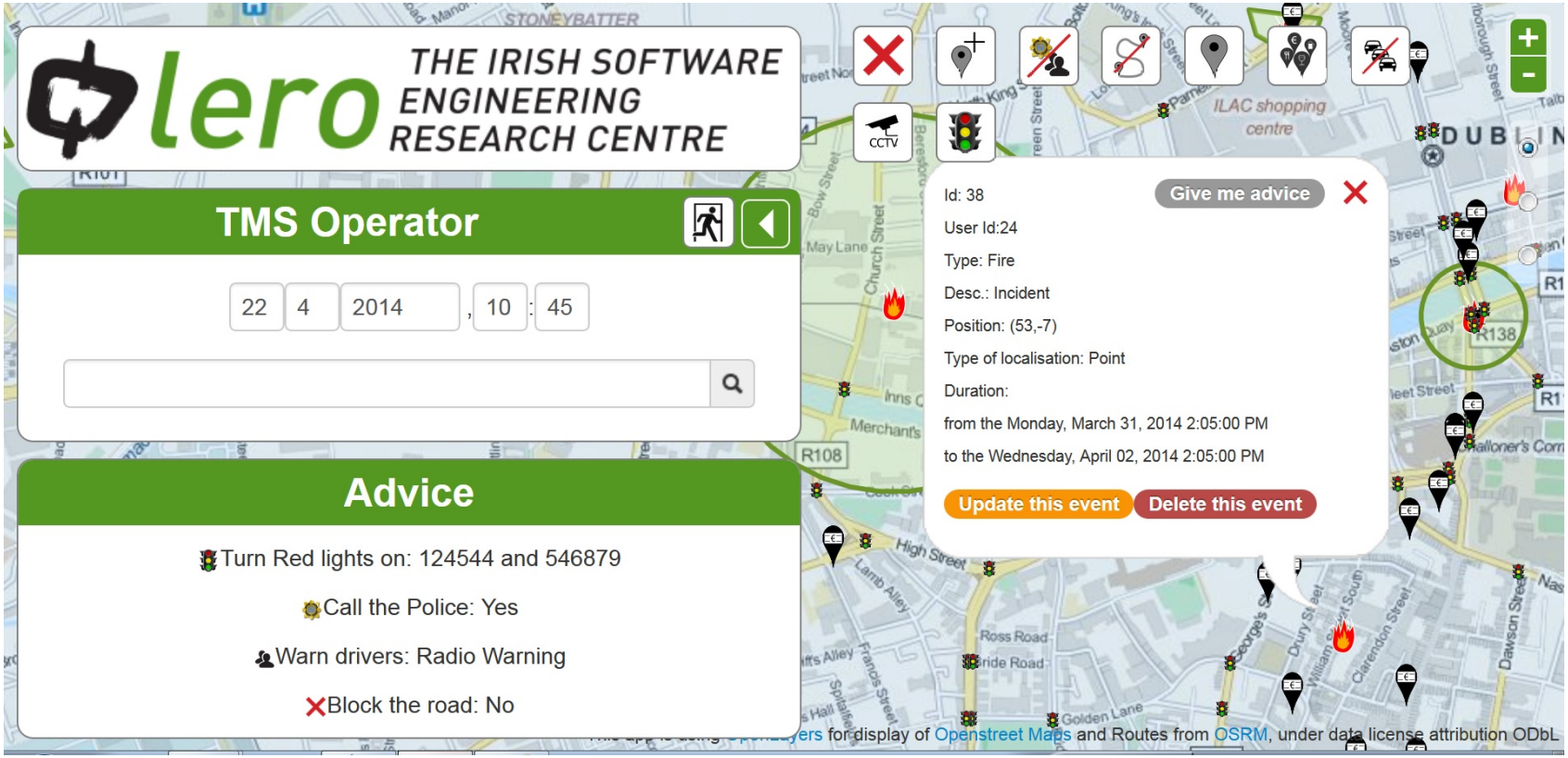
- The goal is to identify automatically the optimum response to a given threat (e.g., explosion, fire) and to potentially activate the resposne.

- In smart cities:
  - Assets are service offices such as banks, hospitals, schools, vehicles, etc.
  - Threats include: fire, shooting, explosion, and looting.
  - Security measures include: change traffic light phases, block streets, send police patrols, TV and Radio warning, etc.

- We use an adaptive security model (a fuzzy neural network) that adapts the security mechanisms based on changes to the asset values.

(Second) Adaptive Security for Smart City

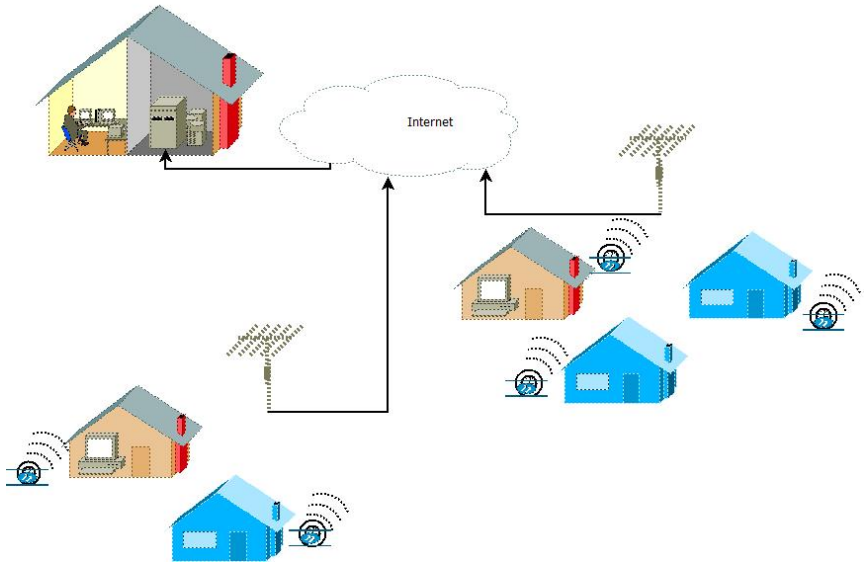
The system computes the asset values and provides advices about the best response-- as a response to an emergency call e.g., automatic change of the phases of selected traffic lights.



(Third) Smart Water Metering

- The main goal of the project is to detect water leakage from water consumption behavioral changes and to control use of water

- Each water meter is equipped with a water limiter, a control unit and a wireless unit



- Water meters send data periodically to the back office and are accessible remotely

- Collected data are mined for identification of water consumption behavior, Pattern of water usage

Need for CPS

CPSs help solving key challenges of our society, such as mobility, safety, control of energy use, limited resources, and the ageing population.

Recall - Software Architecture

The software architecture of a program or computing system is the structure or structures of the system, which comprise software elements, the externally visible properties of those elements, and the relationships among them.

L.Bass, P.Clements, R.Kazman, Software Architecture in Practice (2nd edition), Addison-Wesley 2003

CPS Components and Connectors

- Cyber family
  - Cyber components – data store, computation, IO interface
  - Cyber connectors – call-return, publish/subscribe
- Physical family
  - Physical components – sensing, acting
  - Physical connectors: power flow

Characteristics of CPS

1. Real-time information
2. Autonomous systems
3. Adaptive systems
4. Evolving systems
5. Easy attacked

Security risks for Connected Vehicles

Likelihoods of threats to connected vehicles

Threat	Very unlikely or more vs. Impossible
Sending deceptive messages to the infotainment system	89%
Falsification of speedometer reading of the vehicle	89%
Disruption of the braking system of the vehicle	78%
Disruption of the emergency response system of the vehicle (e.g., OnStar)	78%
Generating false check lights in the dashboard on the vehicle	78%
Locking the gearstick in a fixed position	67%
Remotely updating the firmware of an electrical control units	33%

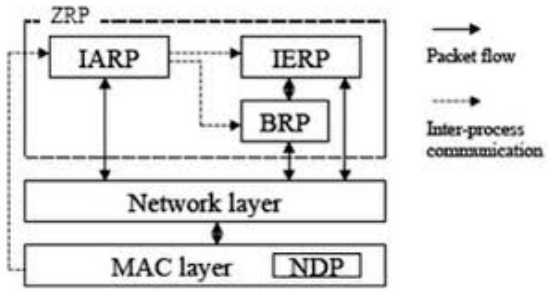
Examples of Challenges of Interest for IS

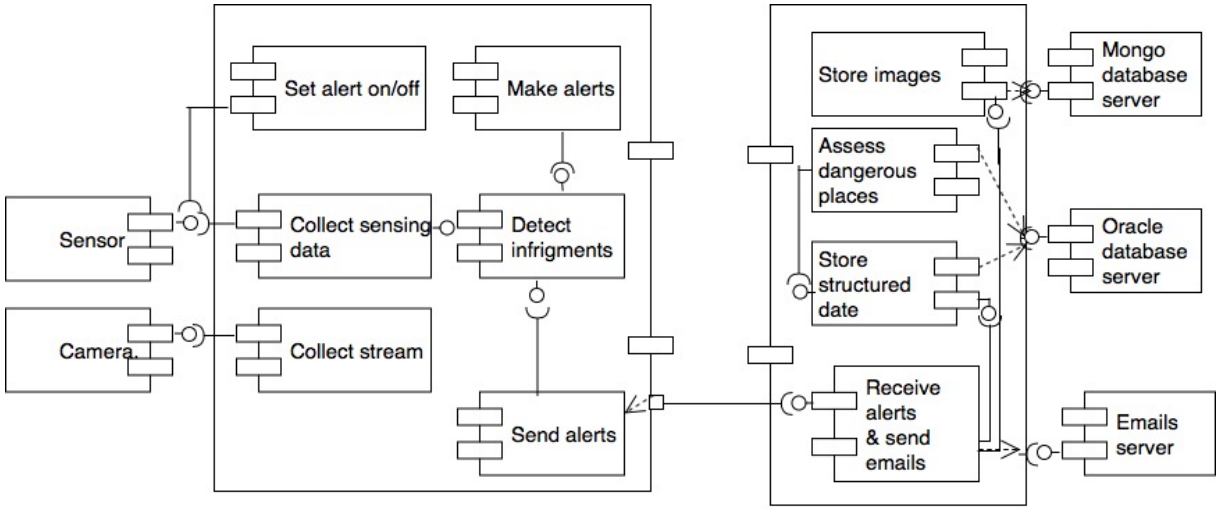
- Shared data consistency
- Fault tolerance
- Deployment of applications
- Performance of applications
- Scalability of applications
- Data storage and retrieval
- Data mining/analytics
- Complexity of the flow of data

Examples of Challenges of Interest for CPS

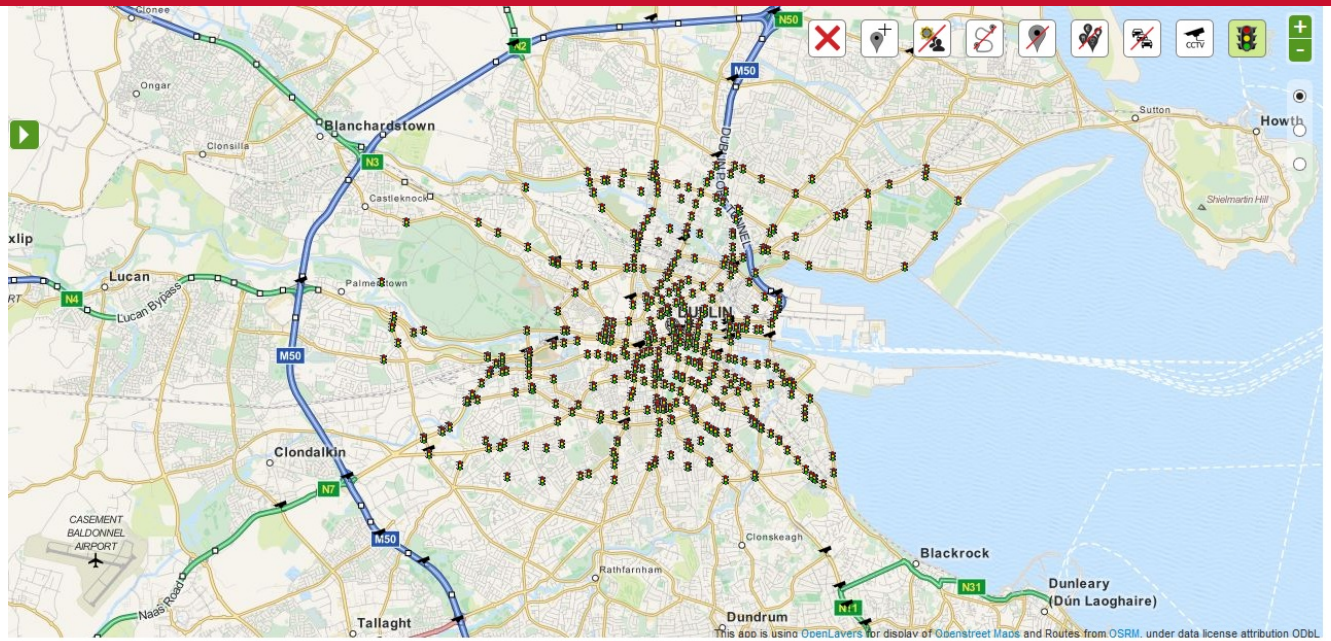
1. Devices are diverse
2. Number of devices is important
3. Communication is Intermittent
4. Messages are frequent and small
5. Processing capabilities are limited
6. Size of data is important
7. Actions are time-critical

Requirement – Support Diverse Devices





Requirement – Support Important Number of Devices

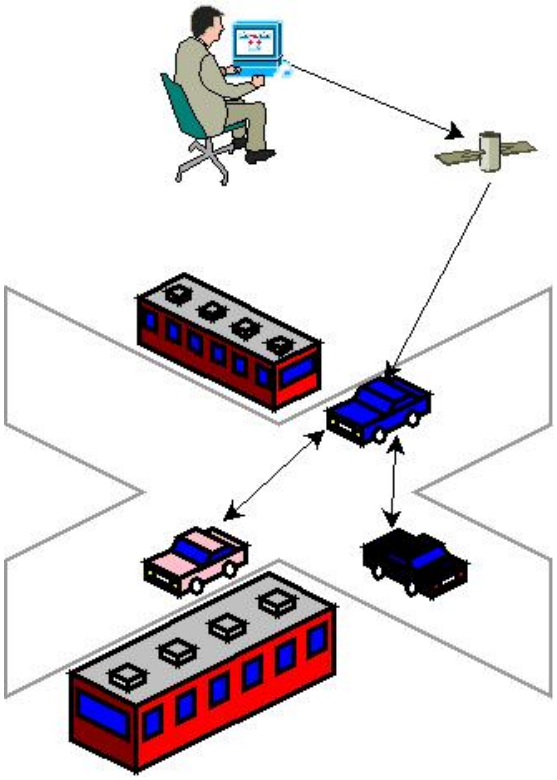


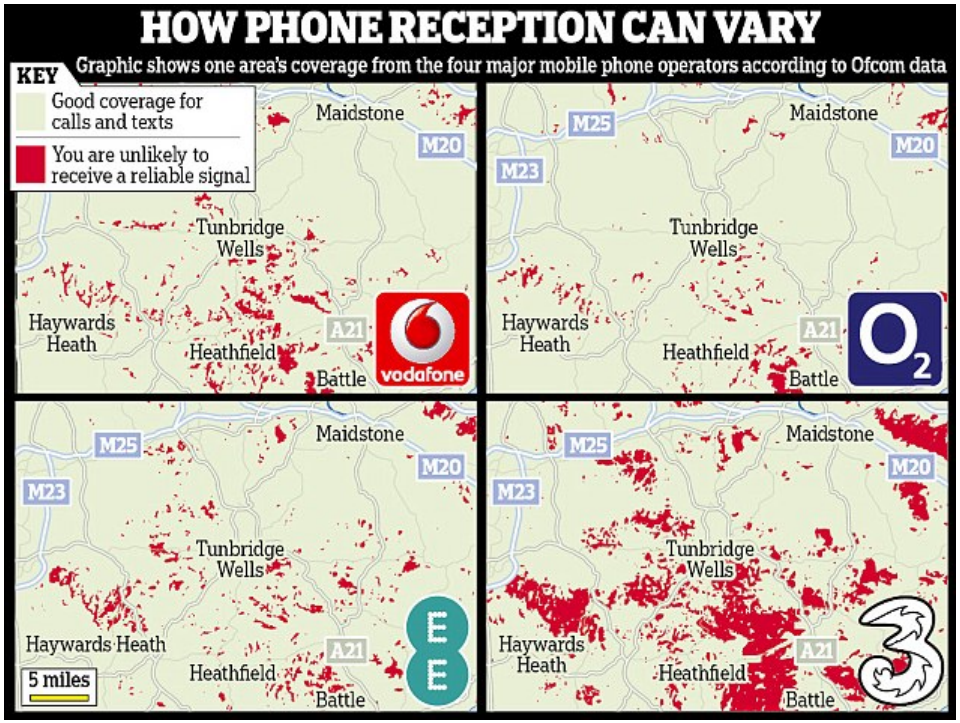
How many traffic lights are in Manhattan interview?

Estimate the number of horizontal blocks and vertical blocks, and then the number of street **lights** on each. Then multiply by 5 to account for the other 5 boroughs. It turns out there are approximately 300,000 street **lights** in NYC, according to NYC.gov.

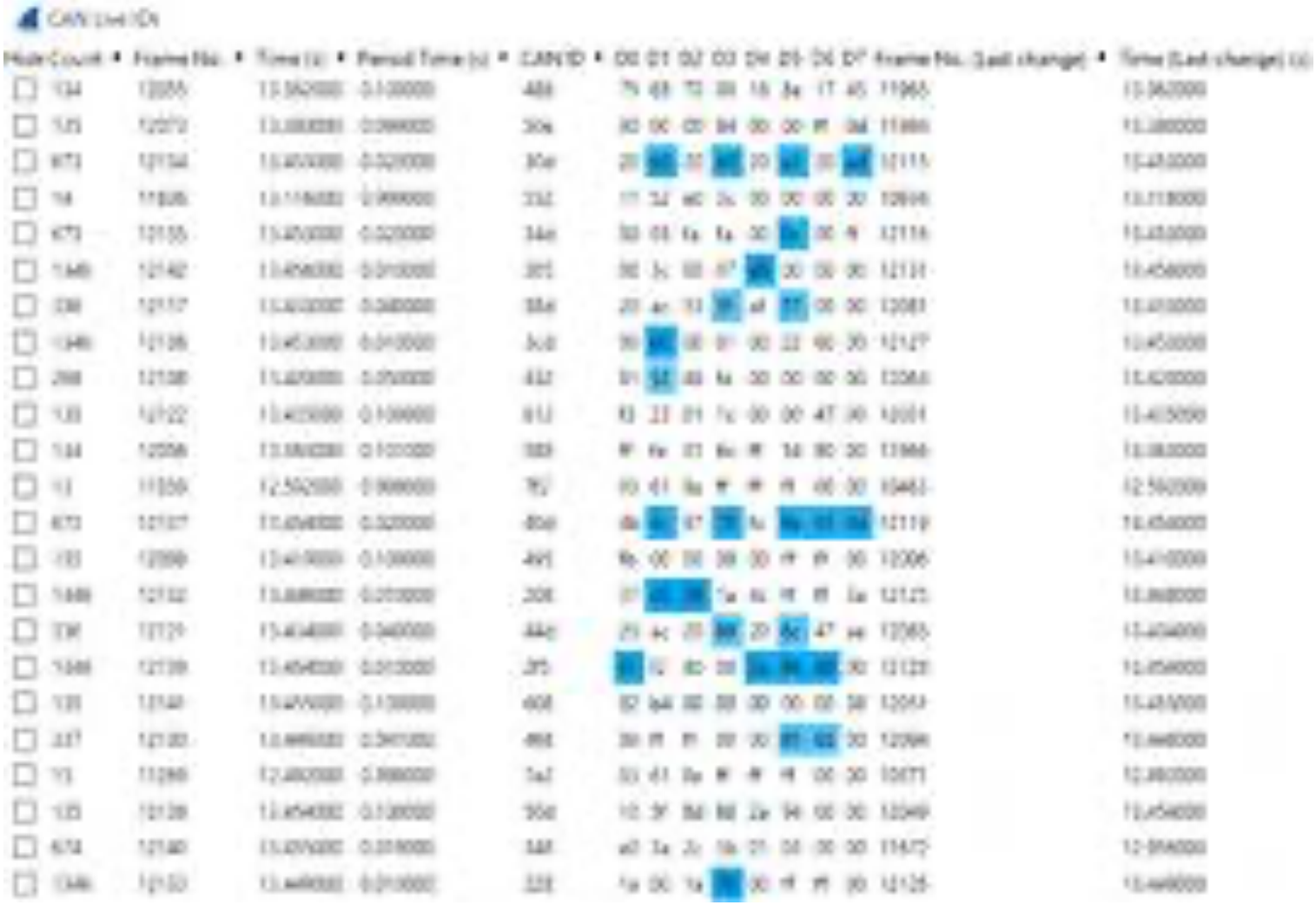
Jul 10, 2013

Requirement – Continue to Operate When Communication is Intermittent





Requirement – Support Frequent and Small Messages



Requirement – Support Limited Processing Capabilities

Intel P8051 microcontroller
12 MHZ

111 ratings
56 answered questions

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Style: **2.2GHZ Dual Core i7**

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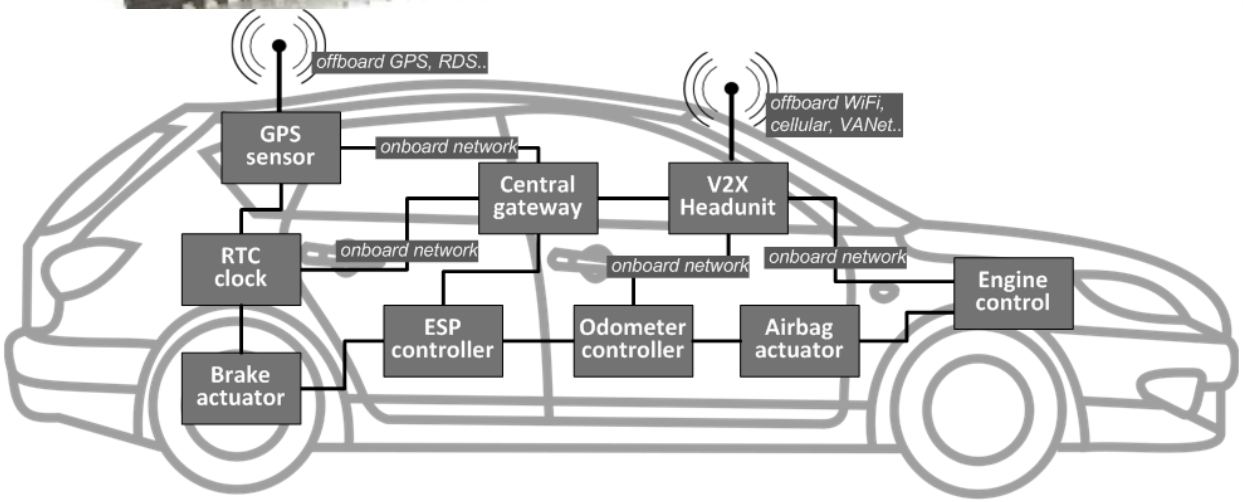
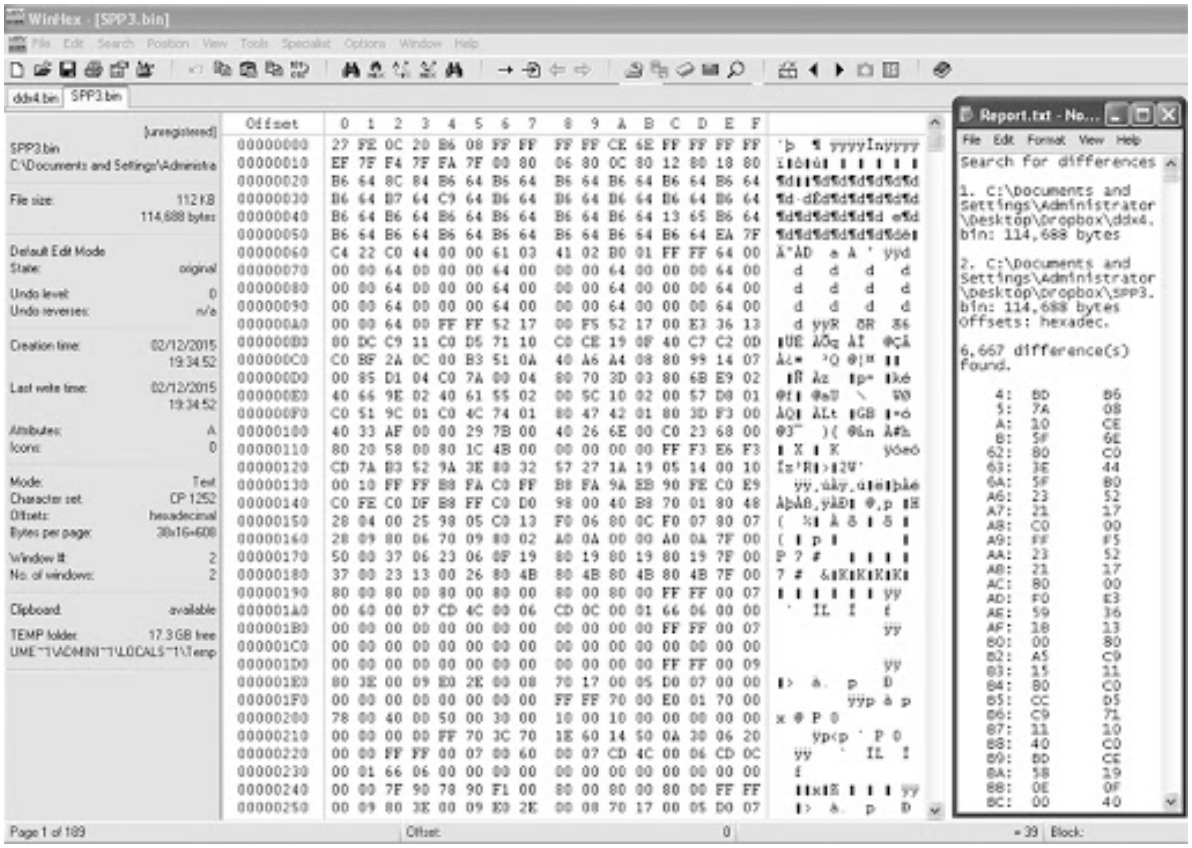


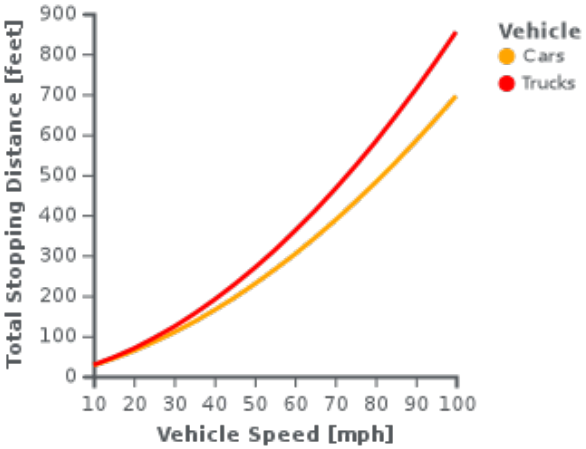
Requirement – Support Big Size of Data

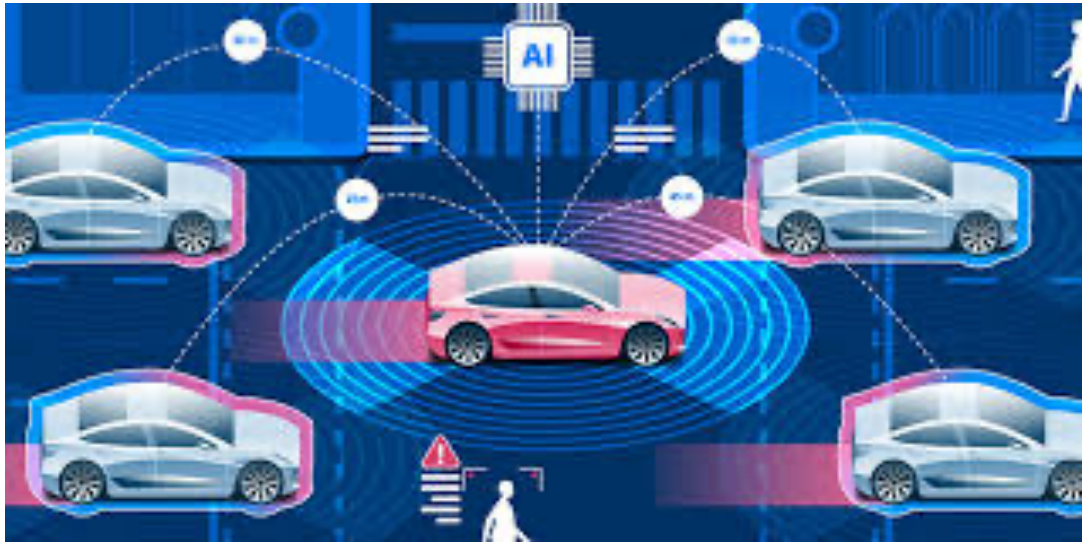
The quantity of messages exchanged in a car are in thousands every second



Requirement – Enforce Time-Critical Actions

Break reaction time is 0.75 second

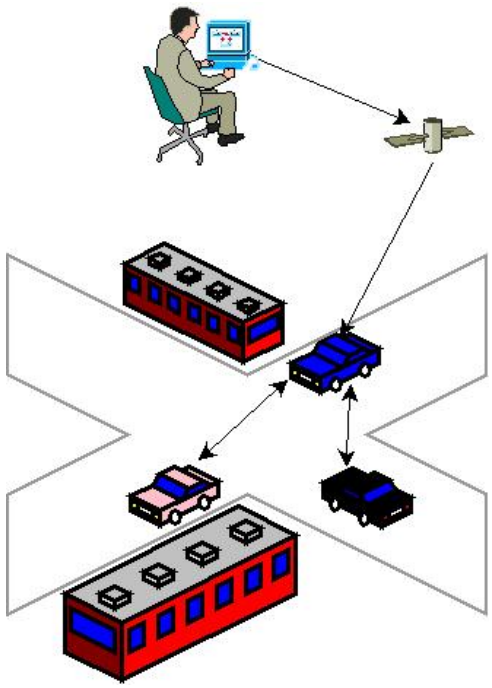




Practice 8: Example of Problems of Interest for CPS

Which issues from the list below apply to fleet management software?

1. Messages are small
2. Devices are diverse
3. Communication is Intermittent
4. Messages are frequent
5. Processing capabilities are limited
6. Size of data is important
7. Actions are time-critical
8. The number of devices is important



Self-Check

1. What is a CPS? Give an example.

2. What are the architecture problems of interest for CPS?

Thank you

Questions?