

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.



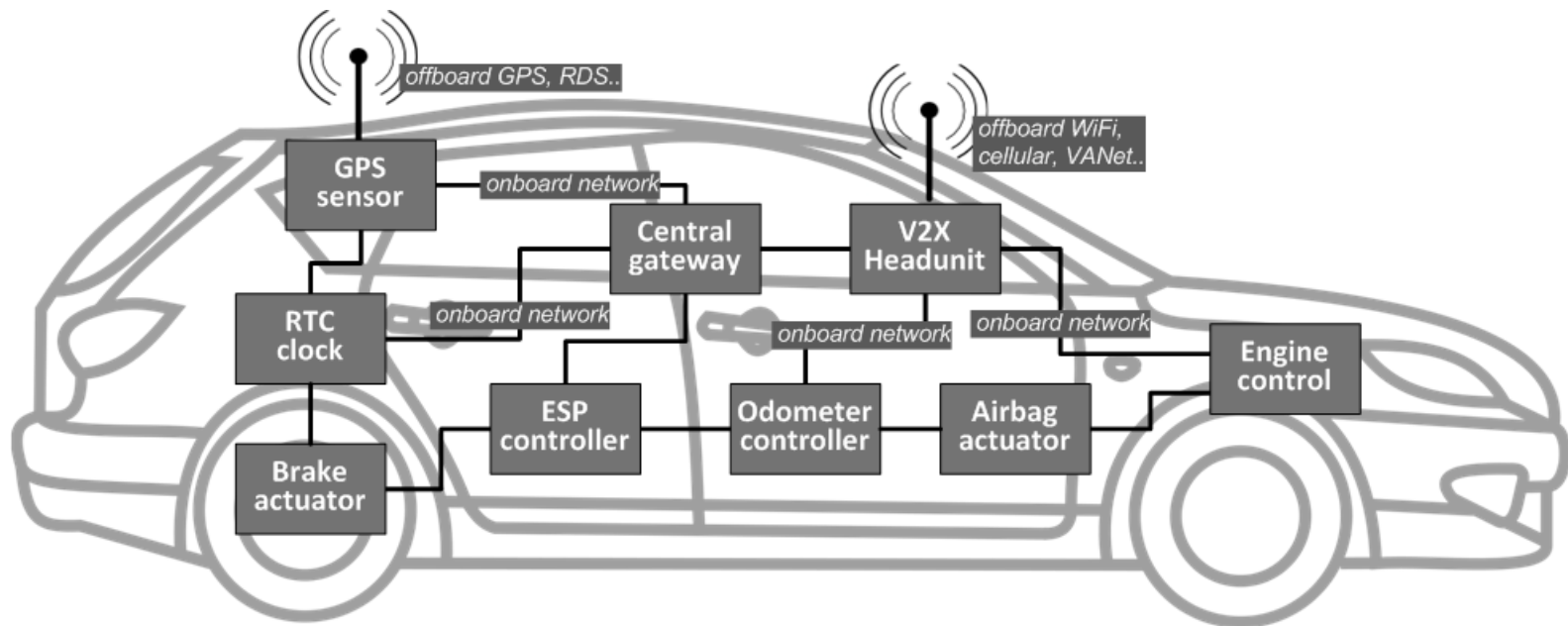
"The new automated ordering system has really speeded up our business. We're losing customers faster than ever."



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>

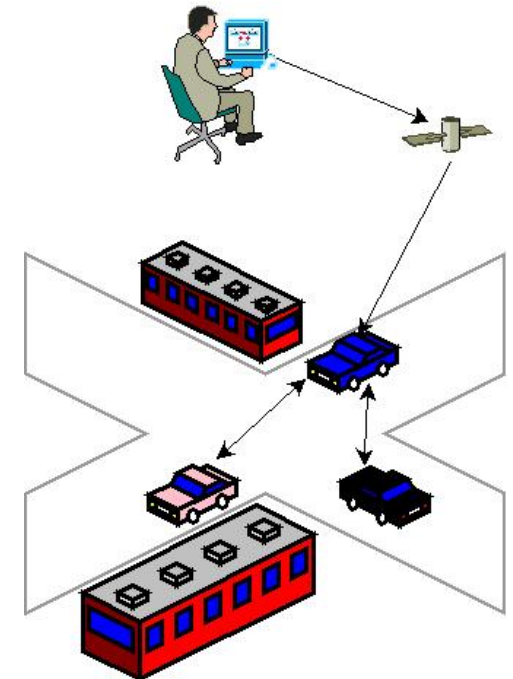
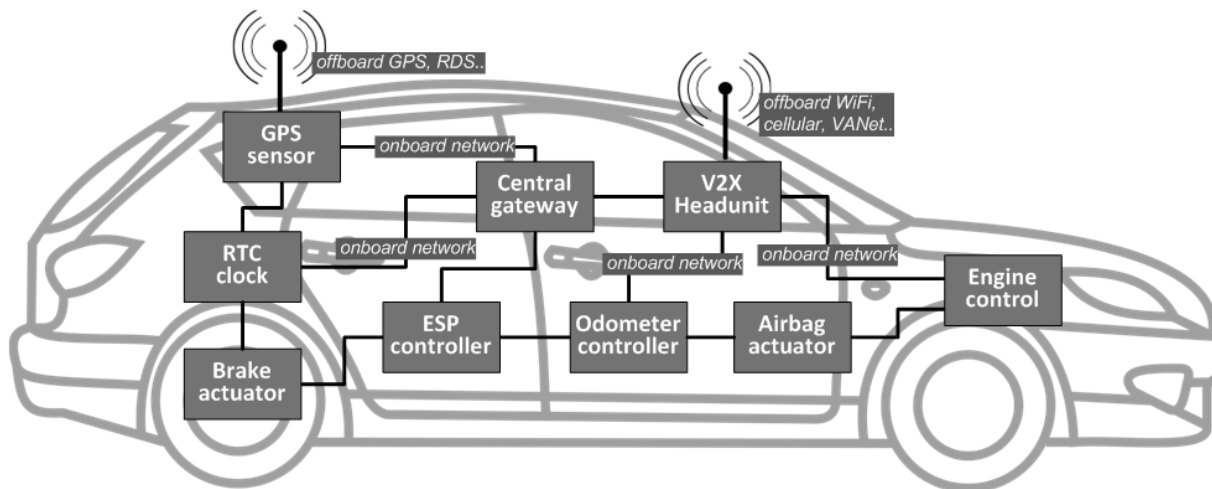


Cyber-physical system

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

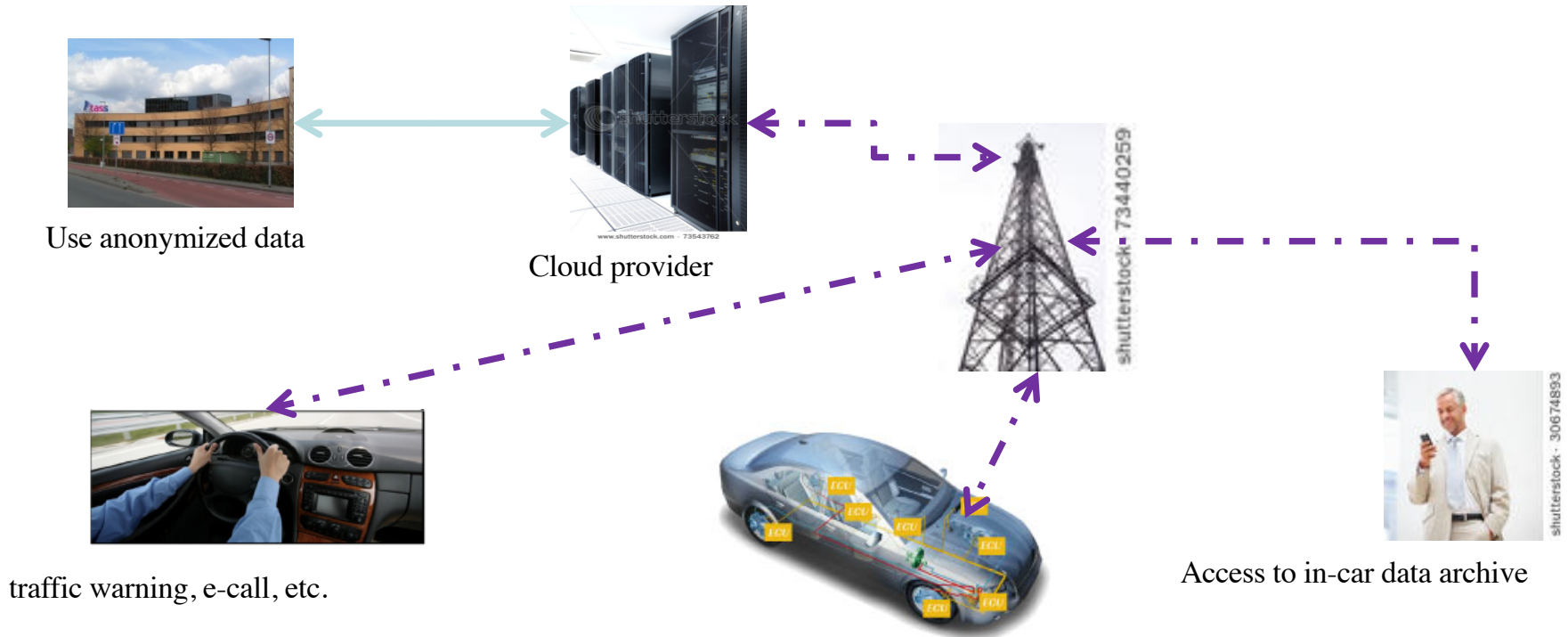
(First) The uCAN System

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.

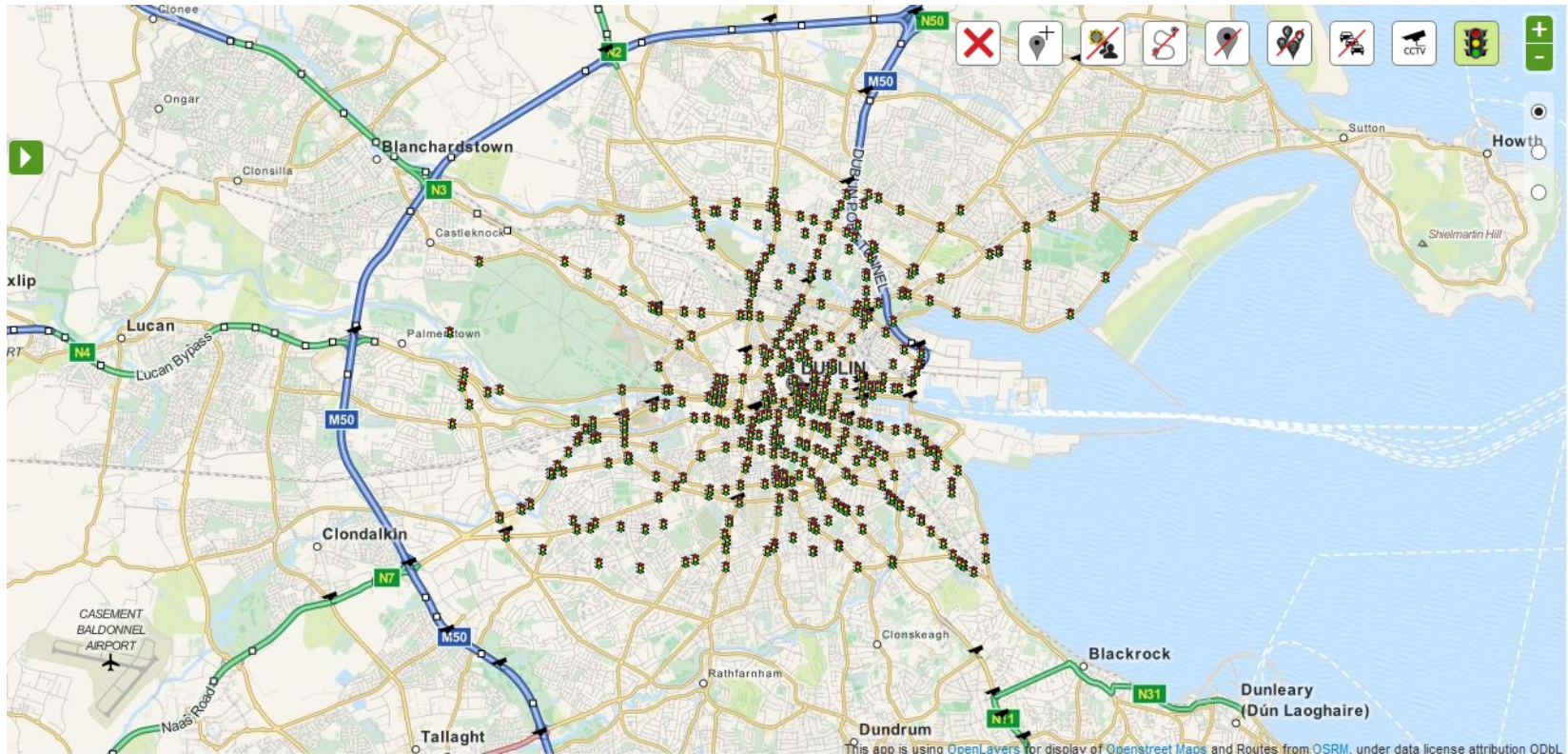


(First) The uCAN System

- 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.

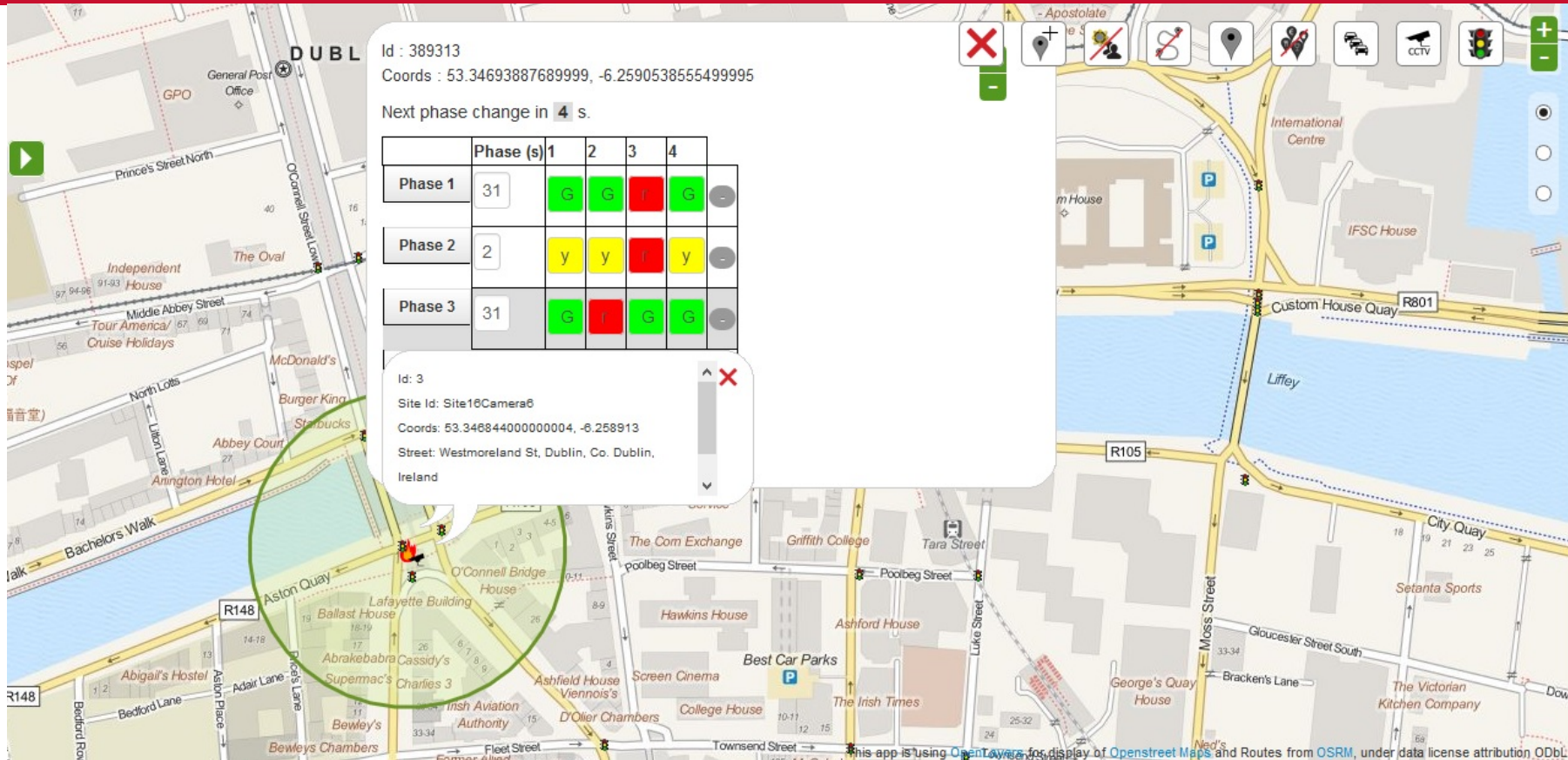


(Second) Adaptive Security for Smart City



- 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 response.
- 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.

The screenshot displays the lero TMS Operator interface. At the top left is the logo for lero, THE IRISH SOFTWARE ENGINEERING RESEARCH CENTRE. Below it is the 'TMS Operator' section with a date and time input field (22/4/2014, 10:45) and a search bar. The 'Advice' section lists four recommendations: 'Turn Red lights on: 124544 and 546879', 'Call the Police: Yes', 'Warn drivers: Radio Warning', and 'Block the road: No'. On the right, a map shows a fire incident at coordinates (53,-7) with a 'Give me advice' button and 'Update this event'/'Delete this event' options. The map also shows various traffic light icons and a 'cctv' icon.

lero THE IRISH SOFTWARE ENGINEERING RESEARCH CENTRE

TMS Operator

22 / 4 / 2014 , 10 : 45

Advice

- Turn Red lights on: 124544 and 546879
- Call the Police: Yes
- Warn drivers: Radio Warning
- Block the road: No

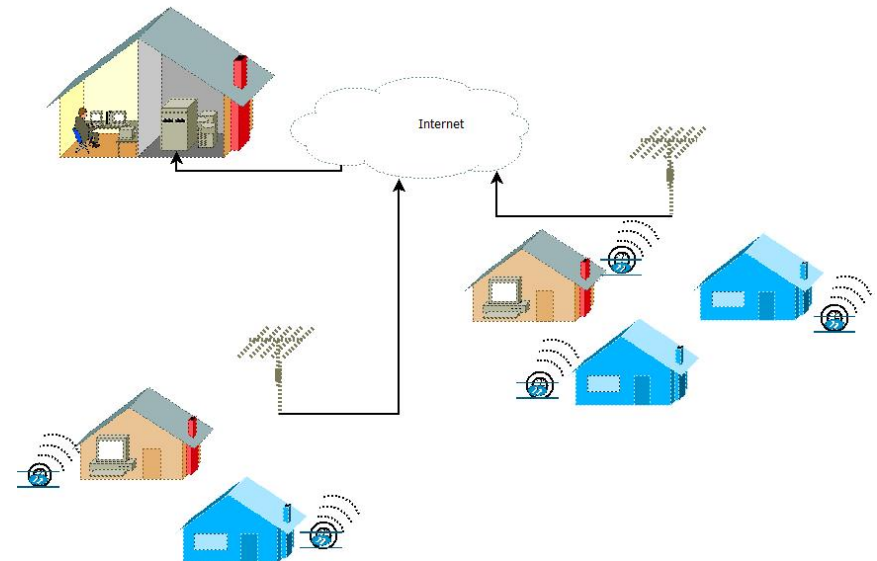
Id: 38
User Id:24
Type: Fire
Desc.: Incident
Position: (53,-7)
Type of localisation: Point
Duration:
from the Monday, March 31, 2014 2:05:00 PM
to the Wednesday, April 02, 2014 2:05:00 PM

Update this event Delete this event

Give me advice

(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%

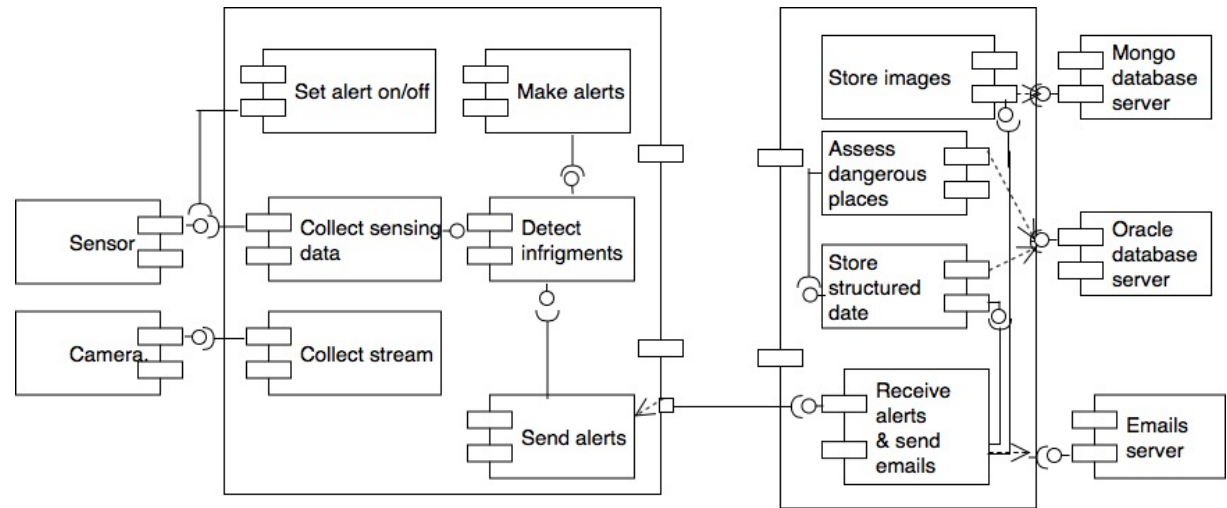
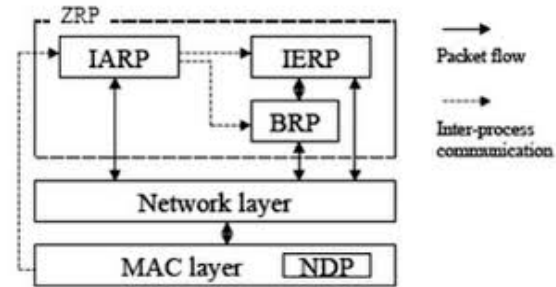
Examples of Challenges of Interest for IS

- 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

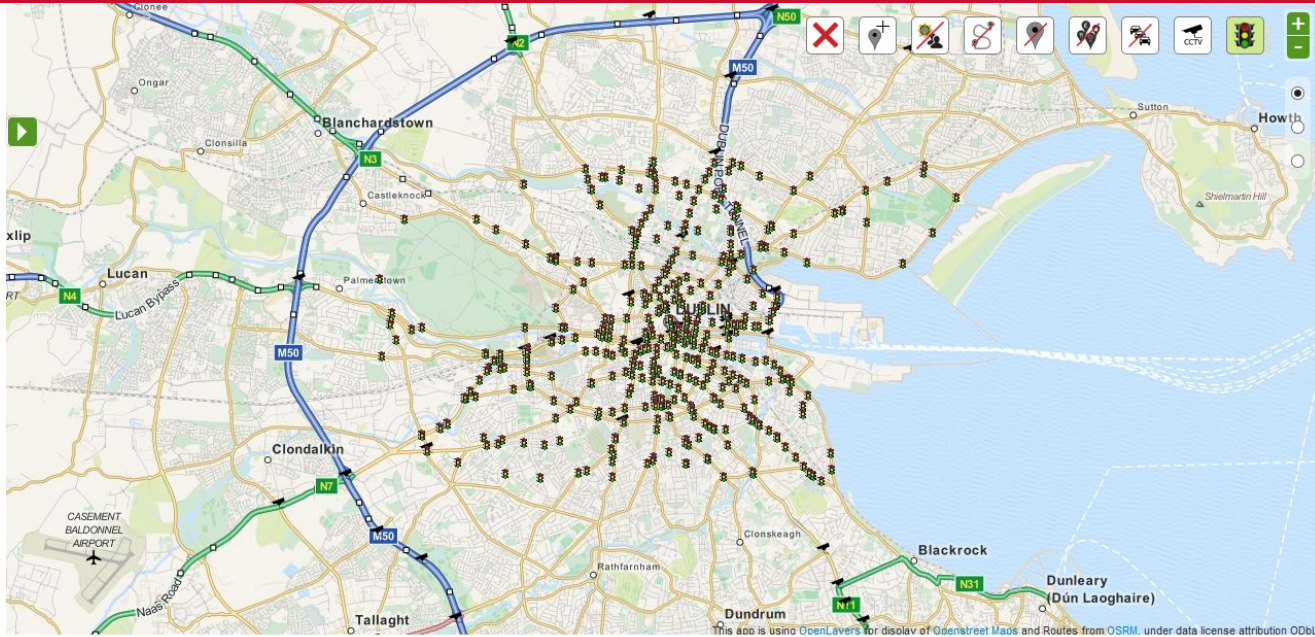
Examples of Challenges of Interest for CPS

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

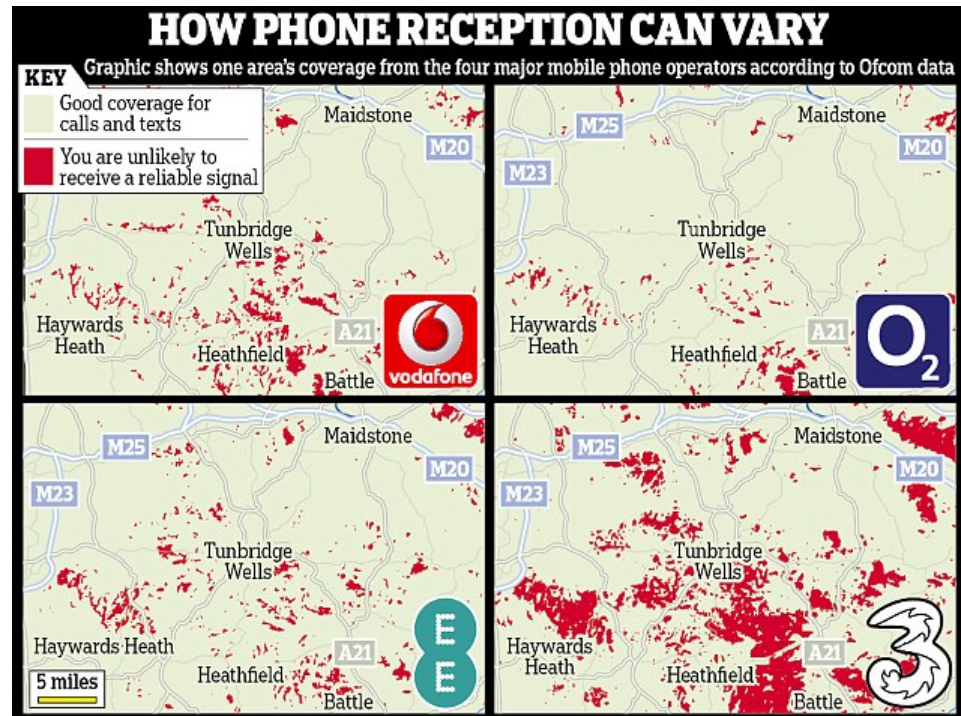
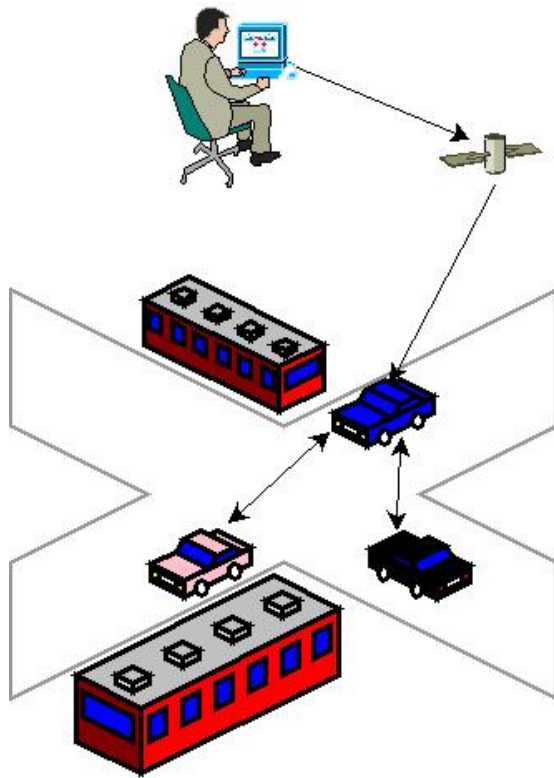


How many traffic lights are in Manhattan interview?

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

CanViewDA

File Count	Frame No.	Time (s)	Period Time (s)	CAN ID	D0 D1 D2 D3 D4 D5 D6 D7	Frame No. (last change)	Time (Last change) (s)	
<input type="checkbox"/>	134	12055	13.342000	0.100000	48a	75 48 72 38 18 3a 17 45	11965	13.342000
<input type="checkbox"/>	135	12070	13.388000	0.090000	30a	30 00 00 04 00 00 00 04	11966	13.388000
<input type="checkbox"/>	873	12134	13.400000	0.020000	30e	20 00 00 20 00 00 00 00	12111	13.400000
<input type="checkbox"/>	14	11926	13.118000	0.090000	232	07 2a 4c 2c 30 00 00 20	10946	13.118000
<input type="checkbox"/>	673	12155	13.470000	0.020000	34e	30 01 1a 1a 30 00 00 00	12116	13.470000
<input type="checkbox"/>	146	12142	13.478000	0.010000	30f	30 2c 00 07 00 00 00 30	12131	13.478000
<input type="checkbox"/>	136	12117	13.420000	0.040000	38a	20 4c 73 00 4f 00 00 30	12081	13.420000
<input type="checkbox"/>	146	12126	13.450000	0.010000	3c0	30 00 00 00 00 22 00 30	12127	13.450000
<input type="checkbox"/>	268	12138	13.470000	0.070000	412	01 3a 48 1a 30 00 00 30	12068	13.470000
<input type="checkbox"/>	133	12122	13.420000	0.100000	612	03 23 01 7c 00 00 47 30	12051	13.420000
<input type="checkbox"/>	144	12058	13.380000	0.100000	383	00 1a 01 6c 00 1a 80 30	11968	13.380000
<input type="checkbox"/>	11	11950	12.502000	0.090000	75	00 41 0a 00 00 00 00 30	10463	12.502000
<input type="checkbox"/>	873	12127	13.458000	0.020000	80e	0a 00 07 00 0a 00 00 00	12119	13.458000
<input type="checkbox"/>	133	12099	13.410000	0.100000	49f	0c 00 00 08 30 00 00 30	12006	13.410000
<input type="checkbox"/>	146	12122	13.468000	0.070000	208	07 00 00 0a 00 00 00 1a	12125	13.468000
<input type="checkbox"/>	136	12127	13.474000	0.040000	44c	21 4c 00 00 20 5c 47 00	12065	13.474000
<input type="checkbox"/>	146	12139	13.480000	0.070000	37f	00 00 00 00 00 00 00 30	12128	13.480000
<input type="checkbox"/>	133	12142	13.475000	0.100000	608	02 0a 00 08 00 00 00 00	12053	13.475000
<input type="checkbox"/>	217	12120	13.468000	0.070000	46a	30 00 00 00 00 00 00 30	12068	13.468000
<input type="checkbox"/>	13	11986	12.480000	0.090000	7a2	03 41 0a 00 00 00 00 30	10871	12.480000
<input type="checkbox"/>	125	12138	13.474000	0.100000	30e	10 3f 0a 00 2a 0a 00 30	12049	13.474000
<input type="checkbox"/>	674	12140	13.476000	0.070000	3a8	4f 2a 2c 1a 01 00 00 30	11672	13.476000
<input type="checkbox"/>	146	12120	13.468000	0.070000	22f	7a 00 7a 00 00 00 00 30	12126	13.468000

Requirement – Support Limited Processing Capabilities

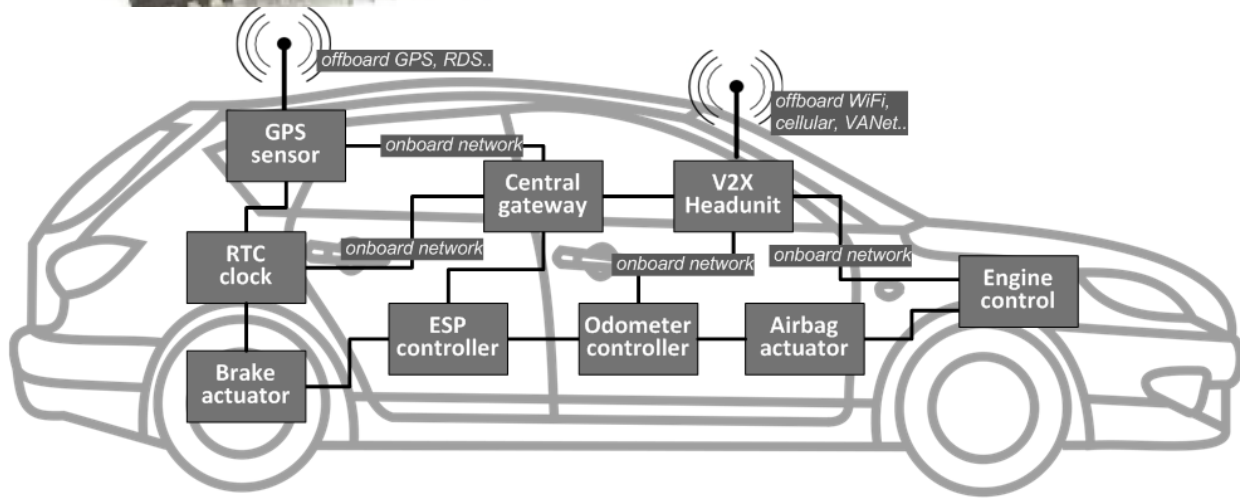
Intel P8051 microcontroller
12 MHZ



Visit the Amazon reference store
★★★★☆ 111 ratings
56 answered questions

Price: **\$749.99 & FREE Shipping**
Get \$50 off instantly: Pay \$699.99 upon approval for the Amazon Rewards Visa Card.

- Style: **2.2GHZ Dual Core i7**
- 2.2GHz Dual Core i7
 - 1.8GHz Dual Core i5
 - 2.2GHZ Dual Core i7**



Requirement – Support Big Size of Data

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

WinHex - [SPP3.bin]

File Edit Search Position View Tools Specialist Options Window Help

dds4 bin SPP3 bin

Offset	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
00000000	27	FE	0C	20	B6	08	FF	FF	FF	FF	CE	6E	FF	FF	FF	FF
00000001	EF	7F	F4	7F	FA	7F	00	80	06	80	0C	80	12	80	18	80
00000002	B6	64	8C	84	B6	64	B6	64	B6	64	B6	64	B6	64	B6	64
00000003	B6	64	B7	64	C9	64	B6	64	B6	64	B6	64	B6	64	B6	64
00000004	B6	64	B6	64	B6	64	B6	64	B6	64	B6	64	13	65	B6	64
00000005	B6	64	B6	64	B6	64	B6	64	B6	64	B6	64	B6	64	EA	7F
00000006	C4	22	C0	44	00	00	61	03	41	02	80	01	FF	FF	64	00
00000007	00	00	64	00	00	64	00	00	00	64	00	00	64	00	00	64
00000008	00	00	64	00	00	64	00	00	00	64	00	00	64	00	00	64
00000009	00	00	64	00	00	64	00	00	00	64	00	00	64	00	00	64
0000000A	00	00	64	00	FF	FF	52	17	00	F5	52	17	00	E3	36	13
0000000B	00	DC	C9	11	C0	D5	71	10	C0	CE	19	08	40	C7	C2	00
0000000C	C0	BF	2A	0C	00	B3	51	0A	40	A6	A4	08	80	99	14	07
0000000D	00	85	D1	04	C0	7A	00	04	80	70	3D	03	80	6B	E9	02
0000000E	40	64	9E	02	40	61	55	02	00	5C	10	02	00	57	D8	01
0000000F	C0	51	9C	01	C0	4C	74	01	80	47	42	01	80	3D	F3	00
00000100	40	33	AF	00	00	29	7B	00	40	26	6E	00	C0	23	68	00
00000101	80	20	58	00	80	1C	4B	00	00	00	00	00	FF	F3	E6	F3
00000102	CD	7A	B3	52	9A	3E	80	32	57	27	1A	19	05	14	00	10
00000103	00	10	FF	FF	B8	FA	C0	FF	B8	FA	9A	E8	90	FE	C0	E9
00000104	C0	FE	C0	DF	B8	FF	C0	D0	98	00	40	B8	70	01	80	48
00000105	28	04	00	25	38	05	C0	13	F0	06	80	0C	F0	07	80	07
00000106	28	09	80	06	70	09	80	02	0A	0A	00	00	A0	0A	7F	00
00000107	50	00	37	06	23	06	0F	19	80	19	80	19	80	19	7F	00
00000108	37	00	23	13	00	26	80	4B	80	4B	80	4B	80	4B	7F	00
00000109	80	00	80	00	80	00	80	00	80	00	80	00	FF	FF	00	07
0000010A	00	60	00	07	CD	4C	00	06	0C	0C	00	01	64	06	00	00
0000010B	00	00	00	00	00	00	00	00	00	00	00	00	FF	FF	00	07
0000010C	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
0000010D	00	00	00	00	00	00	00	00	00	00	00	00	FF	FF	00	09
0000010E	80	3E	00	09	80	2E	00	08	70	17	00	05	D0	07	00	00
0000010F	00	00	00	00	00	00	00	00	FF	FF	70	00	E0	01	70	00
00000200	78	00	40	00	50	00	30	00	10	00	10	00	00	00	00	00
00000201	00	00	00	00	FF	70	3C	70	1E	60	14	50	0A	30	06	20
00000202	00	00	FF	FF	00	07	00	60	00	07	CD	4C	00	06	CD	0C
00000203	00	01	66	06	00	00	00	00	00	00	00	00	00	00	00	00
00000204	00	00	7F	90	78	90	F1	00	80	00	80	00	80	00	FF	FF
00000205	00	09	80	3E	00	09	E0	2E	00	08	70	17	00	05	D0	07

Report.txt - No...

File Edit Format View Help

Search for differences

1. C:\documents and settings\Administrator\Desktop\Dropbox\dds4.bin: 114,688 bytes

2. C:\documents and settings\Administrator\Desktop\Dropbox\SPP3.bin: 114,688 bytes

Offsets: hexadec

6,667 difference(s) Found.

41:	80	86
5:	7A	08
A:	10	CE
B:	5F	6E
62:	80	C0
63:	3E	44
6A:	5F	80
A6:	23	52
A7:	21	17
A8:	C0	00
A9:	FF	F5
AA:	23	52
AB:	21	17
AC:	80	00
AD:	F0	E3
AE:	59	36
AF:	18	13
B0:	00	80
B2:	A5	C9
B3:	15	11
B4:	80	C0
B5:	CC	D5
B6:	C9	71
B7:	11	10
B8:	40	C0
B9:	80	CE
BA:	58	19
BB:	0E	0F
BC:	00	40

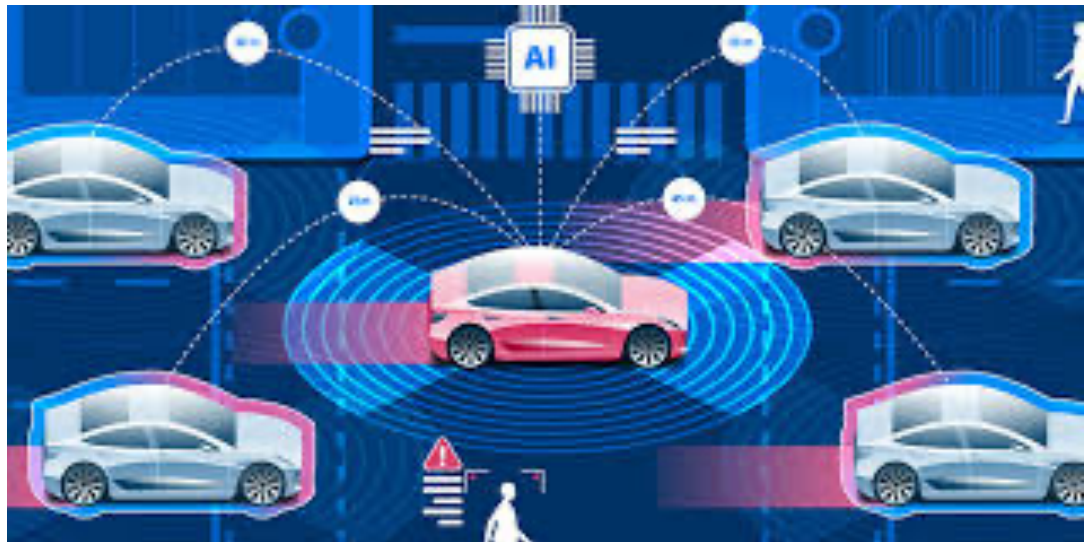
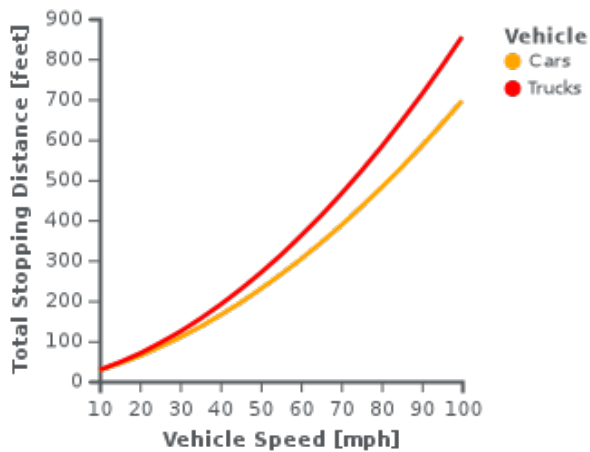
Page 1 of 189

Offset: 0

- 39 | Block:

Requirement – Enforce Time-Critical Actions

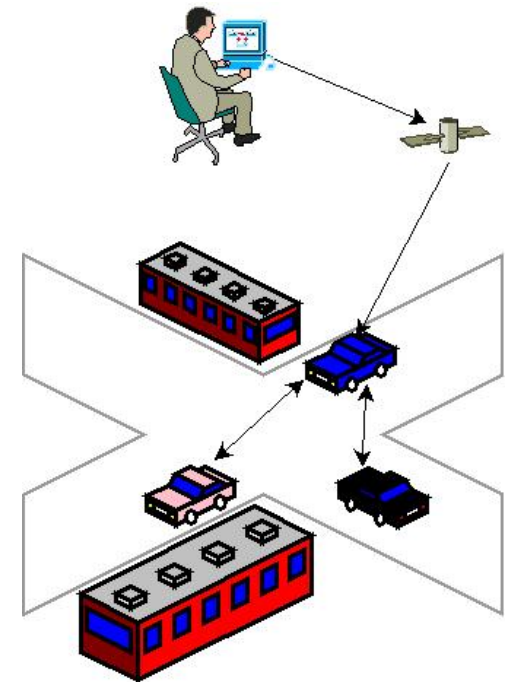
Break reaction time is **0.75 second**



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?