Integrated Security of Wireless Sensor Networks

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Outline

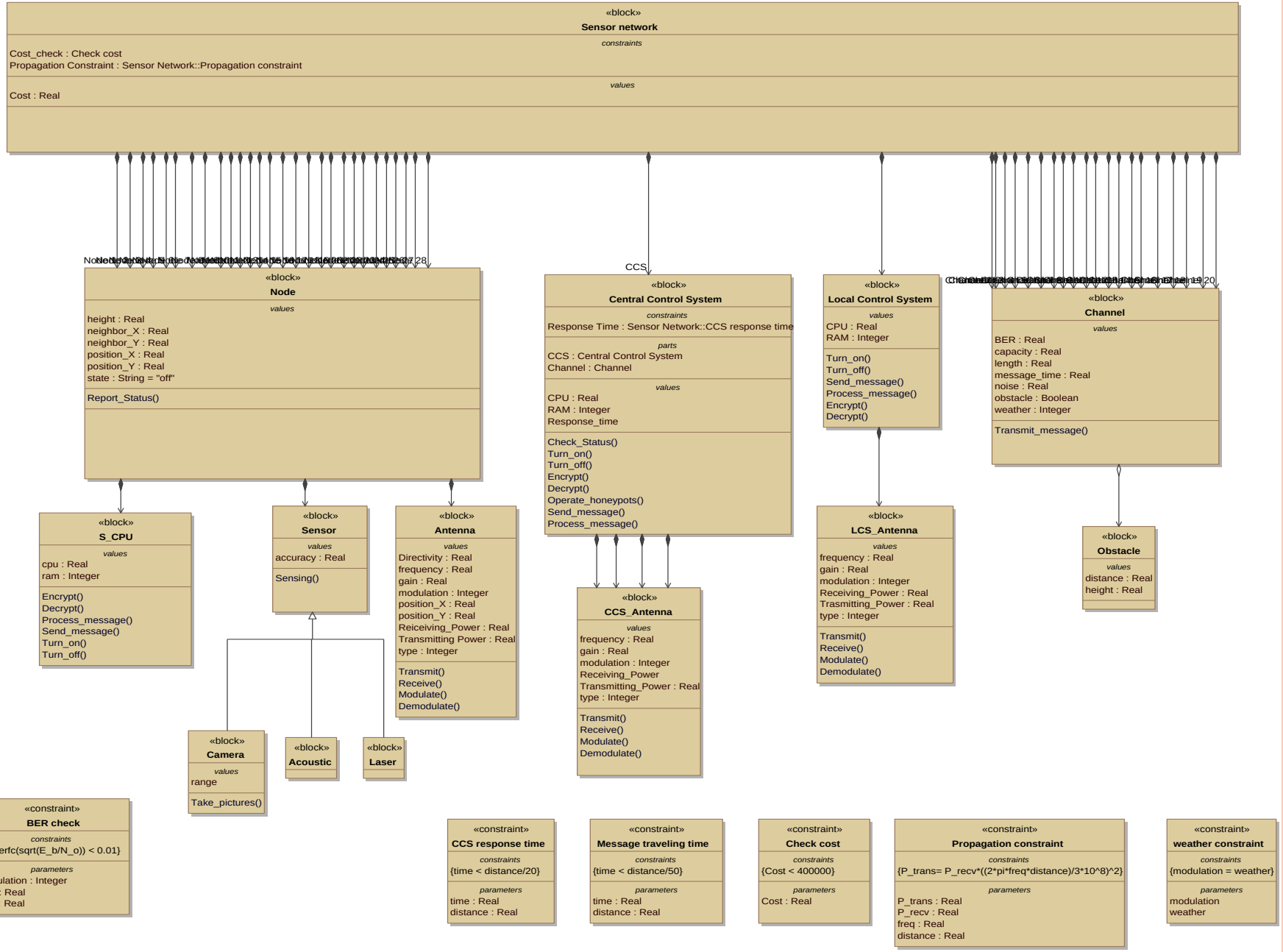
- Project overview
- Structure
- Behavior
  - Use Case
  - Activity Diagram
  - Sequence Diagram
- Requirements
- Trade off analysis

Project Overview

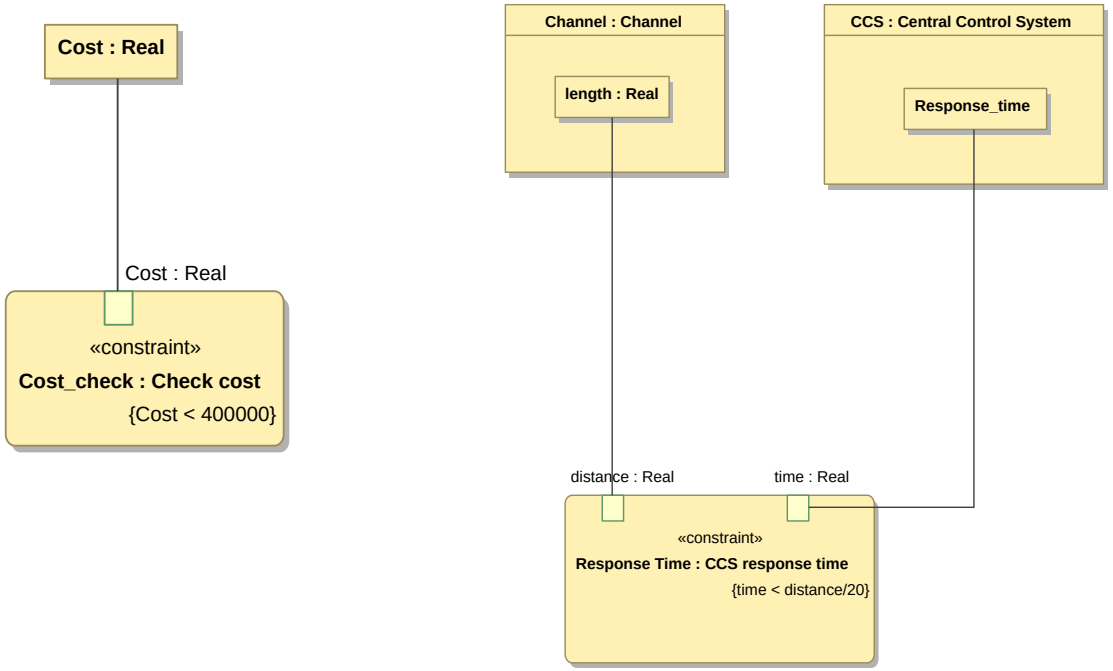
- Our mission is to provide a secure, efficient and cost effective sensor network for the tracking of vehicles in a military base.

- This will be done by
  - Having cameras on the main gate and parking lots
  - Having acoustic and laser sensors on the side of the road

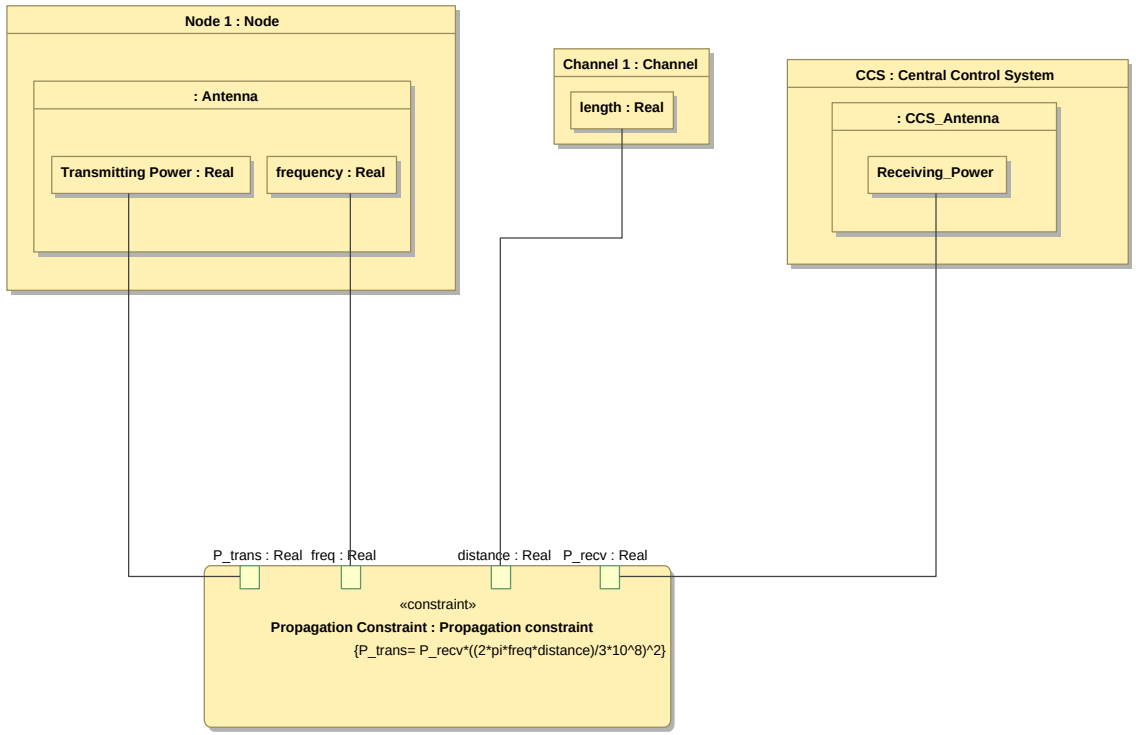
STRUCTURE


«block»
Sensor network
constraints
Cost_check : Check cost
Propagation Constraint : Sensor Network::Propagation constraint
values
Cost : Real
«block»
Node
values
height : Real
neighbor_X : Real
neighbor_Y : Real
position_X : Real
position_Y : Real
state : String = "off"
Report_Status()
CCS
«block»
Central Control System
constraints
Response Time : Sensor Network::CCS response time
parts
CCS : Central Control System
Channel : Channel
values
CPU : Real
RAM : Integer
Response_time
Check_Status()
Turn_on()
Turn_off()
Encrypt()
Decrypt()
Operate_honeypots()
Send_message()
Process_message()
«block»
Local Control System
values
CPU : Real
RAM : Integer
Turn_on()
Turn_off()
Send_message()
Process_message()
Encrypt()
Decrypt()
«block»
Channel
values
BER : Real
capacity : Real
length : Real
message_time : Real
noise : Real
obstacle : Boolean
weather : Integer
Transmit_message()
«block»
S_CPU
values
cpu : Real
ram : Integer
Encrypt()
Decrypt()
Process_message()
Send_message()
Turn_on()
Turn_off()
«block»
Sensor
values
accuracy : Real
Sensing()
«block»
Antenna
values
Directivity : Real
frequency : Real
gain : Real
modulation : Integer
position_X : Real
position_Y : Real
Reiceiving_Power : Real
Transmitting Power : Real
type : Integer
Transmit()
Receive()
Modulate()
Demodulate()
«block»
CCS_Antenna
values
frequency : Real
gain : Real
modulation : Integer
Receiving_Power
Transmitting_Power : Real
type : Integer
Transmit()
Receive()
Modulate()
Demodulate()
«block»
LCS_Antenna
values
frequency : Real
gain : Real
modulation : Integer
Receiving_Power : Real
Trasmitting_Power : Real
type : Integer
Transmit()
Receive()
Modulate()
Demodulate()
«block»
Obstacle
values
distance : Real
height : Real
«block»
Camera
values
range
Take_pictures()
«block»
Acoustic
«block»
Laser
«constraint»
BER check
constraints
{1/2*erfc(sqrt(E_b/N_o)) < 0.01}
parameters
modulation : Integer
N_o : Real
E_b : Real
«constraint»
CCS response time
constraints
{time < distance/20}
parameters
time : Real
distance : Real
«constraint»
Message traveling time
constraints
{time < distance/50}
parameters
time : Real
distance : Real
«constraint»
Check cost
constraints
{Cost < 400000}
parameters
Cost : Real
«constraint»
Propagation constraint
constraints
{P_trans= P_recv*((2*pi*freq*distance)/3*10^8)^2}
parameters
P_trans : Real
P_recv : Real
freq : Real
distance : Real
«constraint»
weather constraint
constraints
{modulation = weather}
parameters
modulation
weather

Parametric Diagrams



Parametric Diagram (Cont.)



Behavior

- Use cases
  - Main gate access
  - Single Vehicle Tracking
  - Intersection
  - Straight line-Acoustic sensors communication
  - Exit from a parking lot-camera acoustic sensor communication
  - Entry in a parking lot.
  - Acoustic sensor battery low

Use Case: Example

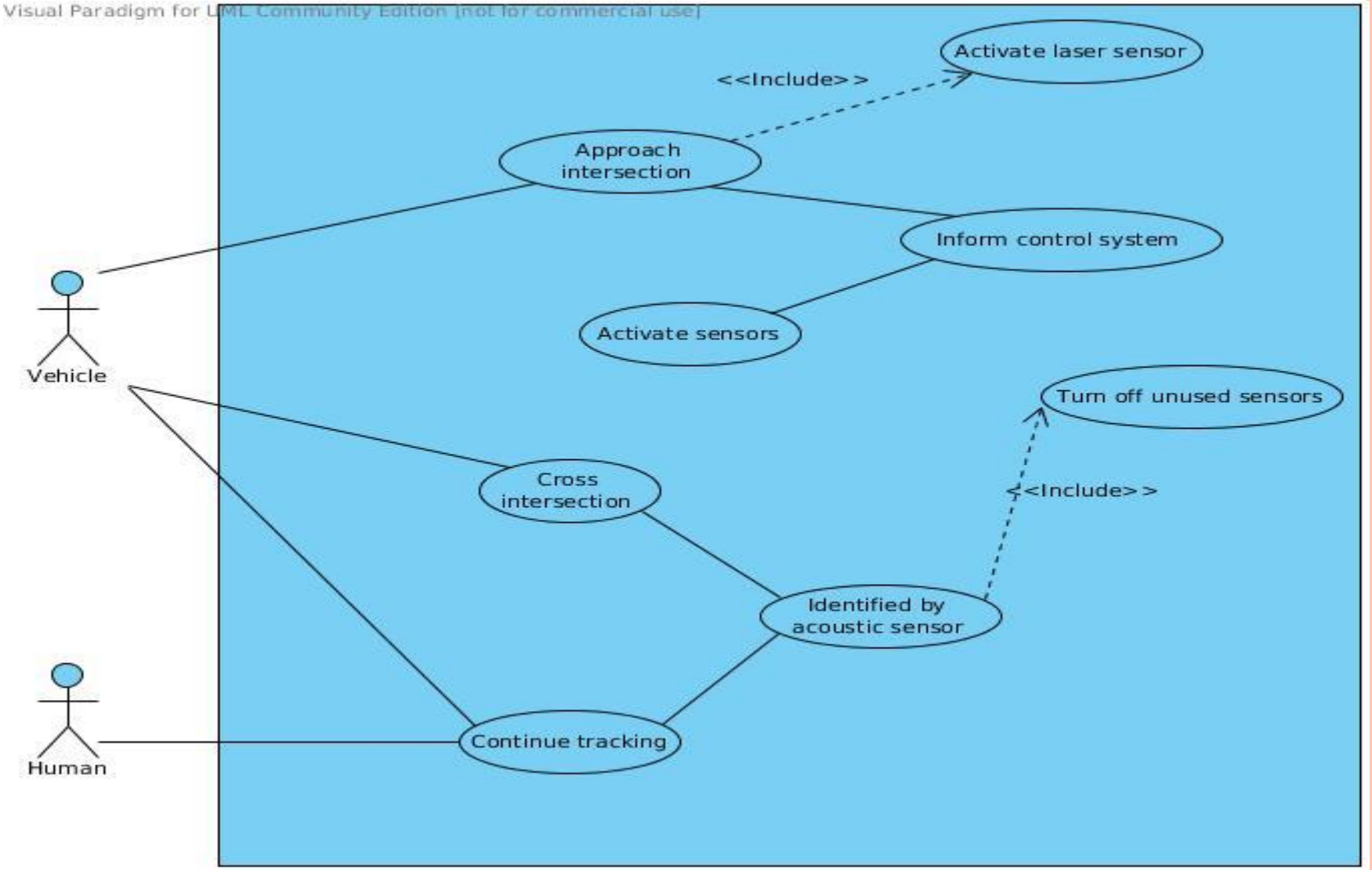
Use Case3. Intersection

Pre-conditions:.Vehicle(s) moves and arrives at an intersection.
Actors: Vehicle, Human
Flow of Events:

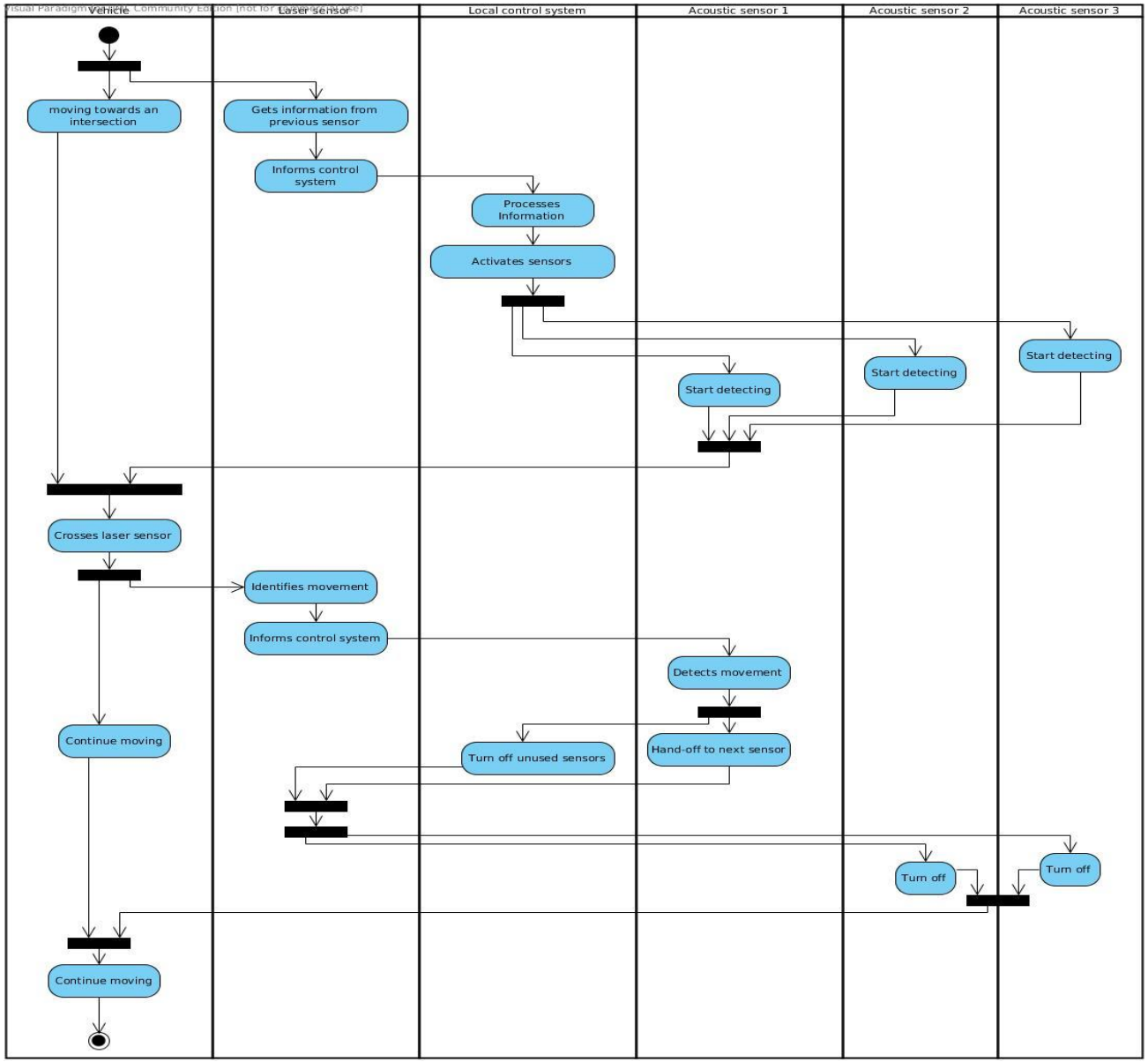
1. Vehicle approaches an intersection.
2. Last acoustic sensor on the straight road segment identifies vehicle and activates laser sensor.
3. Laser sensor informs local control system.
4. The control system activates sensors at the three possible directions.
5 .Vehicle crosses laser sensor.
6. Laser sensor identifies movement and sends message to the local control system.
7. Acoustic sensor identifies the direction of vehicle.
8. Control system turns off sensors that did not detect movement.
9. Tracking continues in a straight segment.

- **Post-conditions:**
  Basic Flow: Moving direction.

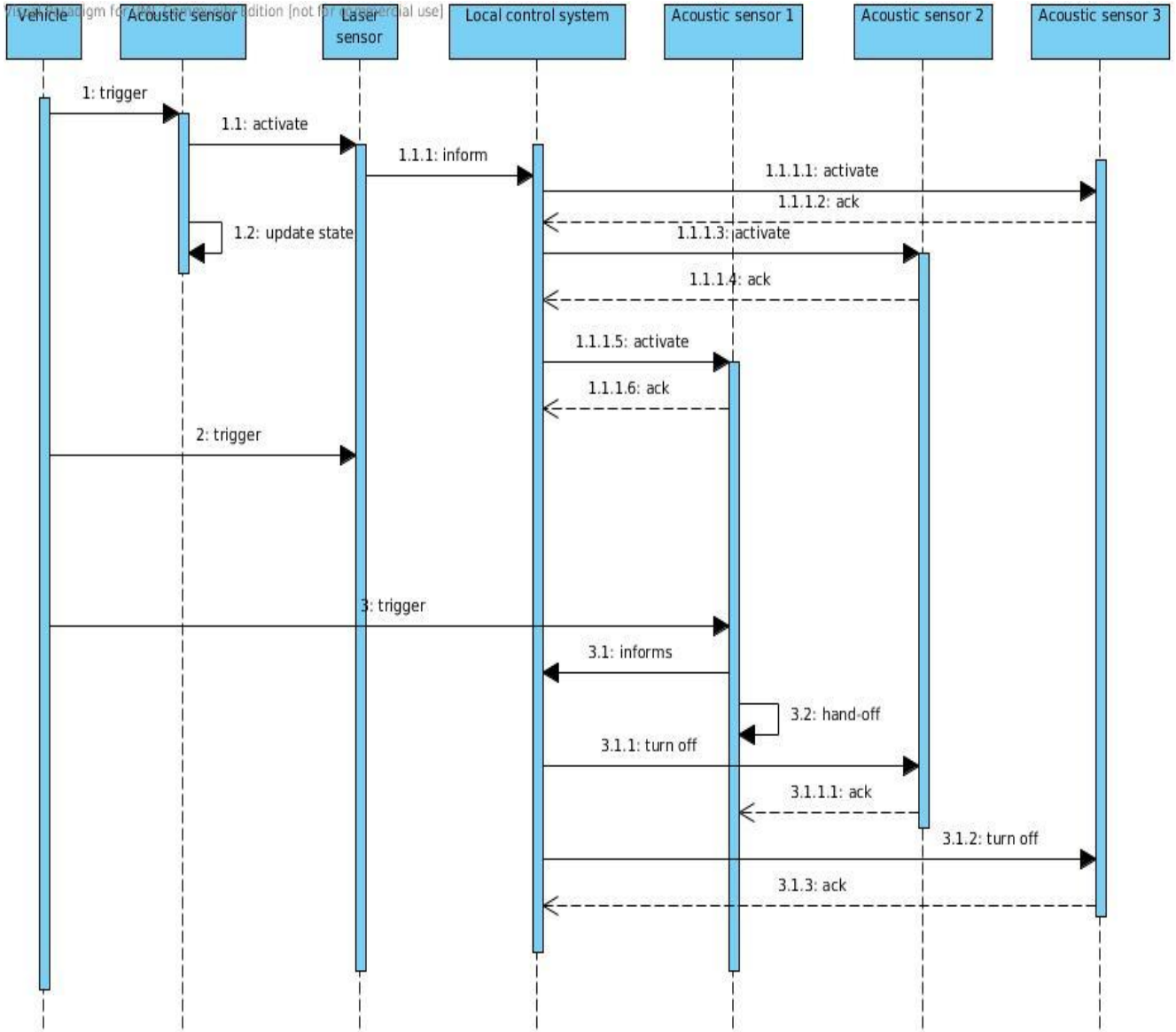
Use Case: Example
Use Case Diagram



Use Case: Example Activity Diagram



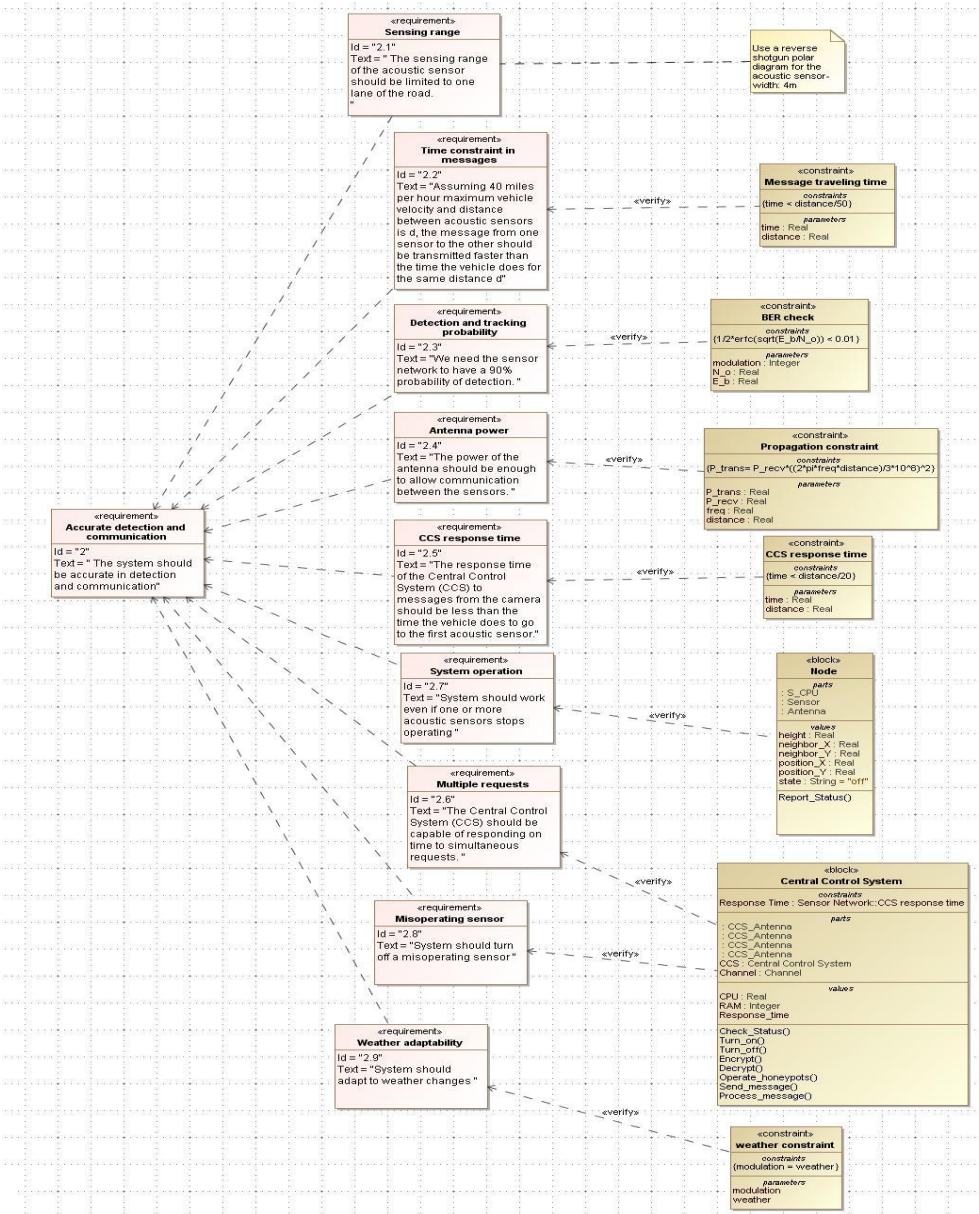
Use Case: Example Sequence Diagram

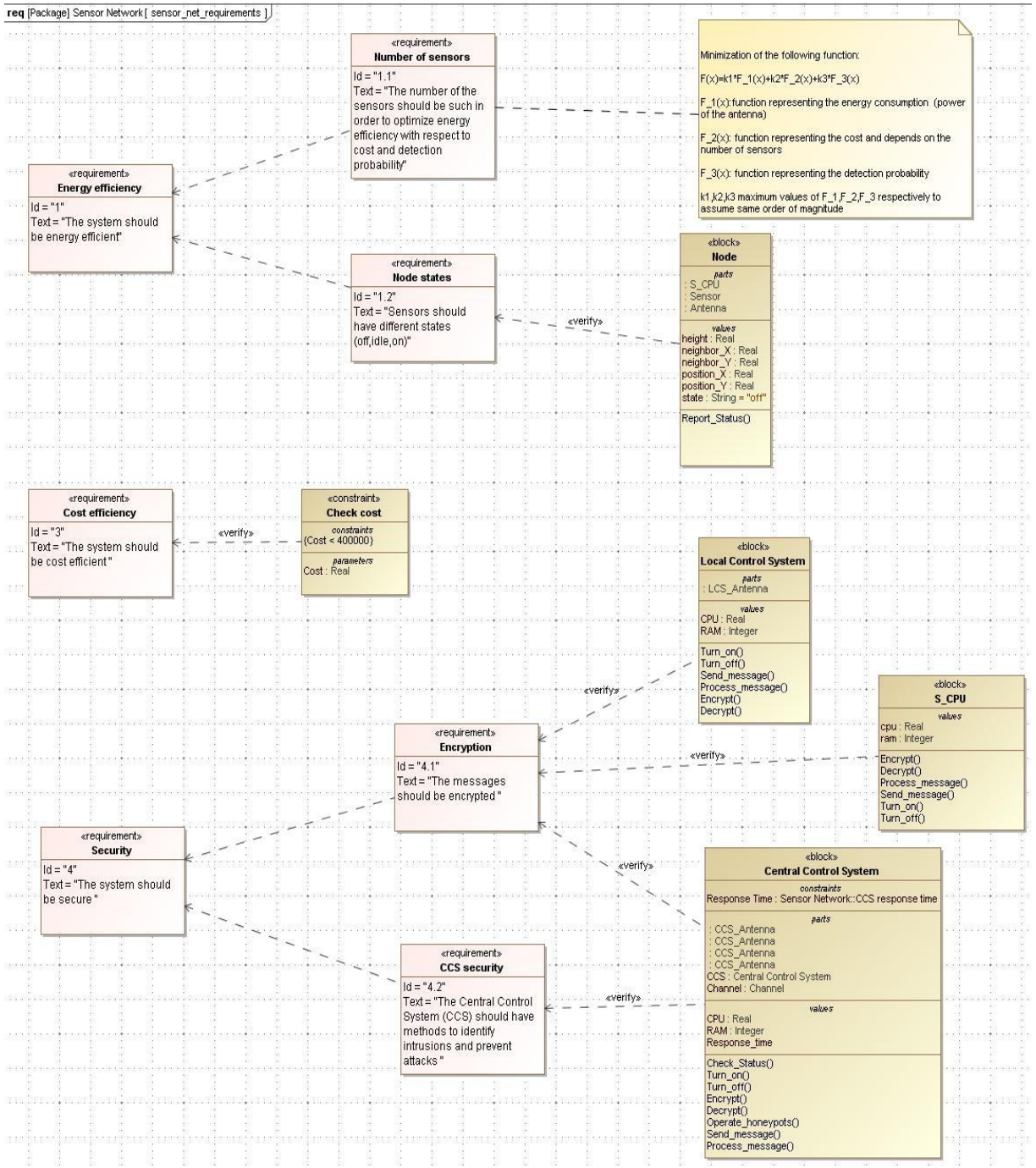


Derived Requirements

Requirement	Behavior	Structure
1.Energy efficiency		
1.1 Number of sensors		X
1.2 Node states	X	
2. Accurate detection and communication		
2.1 Sensing range		X
2.2 Time constraint in messages	X	
2.3 Detection and tracking probability	X	
2.4 Antenna power	X	X
2.5 CCS response time	X	
2.6 Multiple requests	X	
2.7 System operation	X	
2.8 Misoperating sensor	X	
2.9 Weather adaptability	X	
3. Cost efficiency		
4. Security		
4.1 Encryption	X	
4.2 CCS security	X	X

Requirements Diagrams




req [Package] Sensor Network [sensor_net_requirements]
«requirement»
Number of sensors
Id = "1.1"
Text = "The number of the sensors should be such in order to optimize energy efficiency with respect to cost and detection probability"
Minimization of the following function:
F(x)=k1*F_1(x)+k2*F_2(x)+k3*F_3(x)
F_1(x):function representing the energy consumption (power of the antenna)
F_2(x): function representing the cost and depends on the number of sensors
F_3(x): function representing the detection probability
k1,k2,k3 maximum values of F_1,F_2,F_3 respectively to assume same order of magnitude
«requirement»
Energy efficiency
Id = "1"
Text = "The system should be energy efficient"
«requirement»
Node states
Id = "1.2"
Text = "Sensors should have different states (off,idle,on)"
«verify»
«block»
Node
parts
: S_CPU
: Sensor
: Antenna
values
height : Real
neighbor_X : Real
neighbor_Y : Real
position_X : Real
position_Y : Real
state : String = "off"
Report_Status()
«requirement»
Cost efficiency
Id = "3"
Text = "The system should be cost efficient "
«verify»
«constraint»
Check cost
constraints
{Cost < 400000}
parameters
Cost : Real
«block»
Local Control System
parts
: LCS_Antenna
values
CPU : Real
RAM : Integer
Turn_on()
Turn_off()
Send_message()
Process_message()
Encrypt()
Decrypt()
«verify»
«block»
S_CPU
values
cpu : Real
ram : Integer
Encrypt()
Decrypt()
Process_message()
Send_message()
Turn_on()
Turn_off()
«verify»
«requirement»
Encryption
Id = "4.1"
Text = "The messages should be encrypted "
«requirement»
Security
Id = "4"
Text = "The system should be secure "
«verify»
«block»
Central Control System
constraints
Response Time : Sensor Network::CCS response time
parts
: CCS_Antenna
: CCS_Antenna
: CCS_Antenna
: CCS_Antenna
CCS : Central Control System
Channel : Channel
values
CPU : Real
RAM : Integer
Response_time
Check_Status()
Turn_on()
Turn_off()
Encrypt()
Decrypt()
Operate_honeypots()
Send_message()
Process_message()
«requirement»
CCS security
Id = "4.2"
Text = "The Central Control System (CCS) should have methods to identify intrusions and prevent attacks "
«verify»

Requirements

Traceability Matrix

	System Components		
Requirement	Object	Attribute	Function
1.Energy efficiency	Sensor Network		
1.1 Number of sensors	Sensor Network		
1.2 Node states	S_CPU : Node, CCS	state : Node	Turn_on(), Turn_off() : CCS Turn_on(), Turn_off() : S_CPU
2. Accurate detection and communication	Sensor Network		
2.1 Sensing range	Antenna: Node	gain, directivity, position_X, position_Y : Antenna	
2.2 Time constraint in messages	Channel	Length, Message_time: Channel	Transmit_message(): Channel
2.3 Detection and tracking probability			
2.4 Antenna power	Antenna: Node CCS_Antenna: CSS LCS_Antenna: LCS Channel	Receiving Power: Antenna, CCS_Antenna, LCS_Antenna Transmitting_Power: Antenna, CCS_Antenna, LCS_Antenna frequency: Antenna, CCS_Antenna, LCS_Antenna length: Channel	Transmit(): Antenna, CCS_Antenna, LCS_Antenna Receive(): Antenna, CCS_Antenna, LCS_Antenna Modulate(): Antenna, CCS_Antenna, LCS_Antenna
2.5 CCS response time	CCS, Channel	Response_time: CCS length: Channel	Process_message(), Send_message() : CCS
2.6 Multiple requests	CCS	CPU, RAM: CCS	
2.7 System operation	Node		Report_status(): Node
2.8 Misoperating sensor	CCS		Check_status: CCS
2.9 Weather adaptability	Antenna: Node CCS_Antenna: CSS LCS_Antenna: LCS Channel	modulation: Antenna, CCS_Antenna, LCS_Antenna weather: Channel	
3. Cost efficiency	Sensor Network	Cost: Sensor Network	
4. Security	Sensor Network		
4.1 Encryption	S_CPU(Node), CCS, LCS		Encrypt(), Decrypt() : S_CPU, CCS, LCS
4.2 CCS security	CCS		Operate_Honeypots(): CCS

Trade Off Analysis

- Performance Metrics
  - Accuracy, Cost, and energy consumption

Decision Variables:

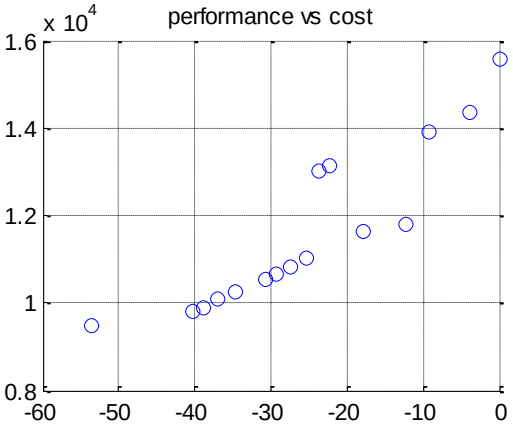
-Sensors: Acoustic, Laser, and Camera

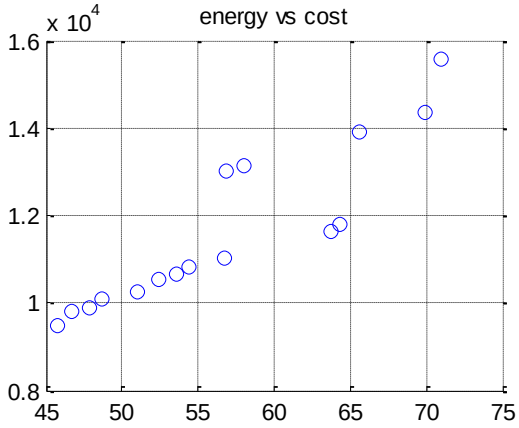
-Control Systems: Local and Central

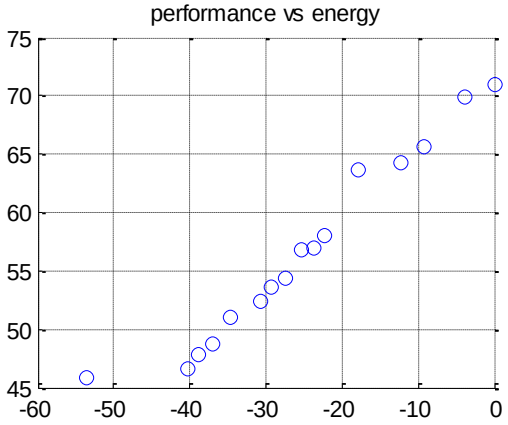
Trade off Scenarios

Point #	X1	X2	X3	Y1	Y2	Y3	Z1	Z2	Z3	L1	L2	L3	C1	C2	C3	cost	performance	energy
1	1			1			1			1			1			1.5816	-53.483	45.812
2	1			1			1			1			1			1.5816	-53.483	45.812
3	1			1			1					1	1			1.6316	-40.1721	46.6691
4	1			1				1				1	1			1.6483	-38.7632	47.8281
5	1			1				1				1	1			1.6483	-38.7632	47.8281
6	1			1					1			1	1			1.6816	-36.9536	48.6616
7	1					1	1					1	1			1.7116	-34.7703	51.0155
8		1		1			1					1	1			1.7566	-30.6256	52.4041
9		1		1			1					1	1			1.7566	-30.6256	52.4041
10		1		1				1				1	1			1.7733	-29.2169	53.5631
11		1		1					1			1	1			1.8066	-27.4071	54.3966
12		1				1	1					1	1			1.8366	-25.2238	56.7505
13		1				1	1					1		1		2.1699	-23.6401	56.9003
14		1				1		1				1		1		2.1866	-22.2315	58.0593
15			1	1			1				1		1			1.94	-17.9567	63.6926
16			1	1			1					1	1			1.965	-12.1421	64.2641
17			1	1				1				1		1		2.315	-9.1498	65.573
18			1			1		1				1		1		2.395	-3.748	69.9193
19			1			1			1			1			1	2.595	0	71

Trade Off Scenarios





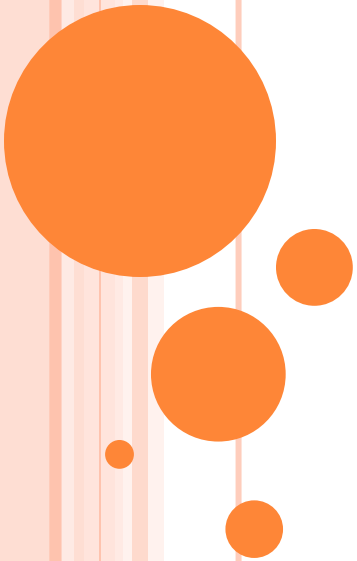


Trade Off Results

- Points of Interest

Point #	cost	performance	energy
2	1.5816	-53.483	45.812
6	1.6816	-36.9536	48.6616
13	2.1699	-23.6401	56.9003

- Best Point



Questions ?