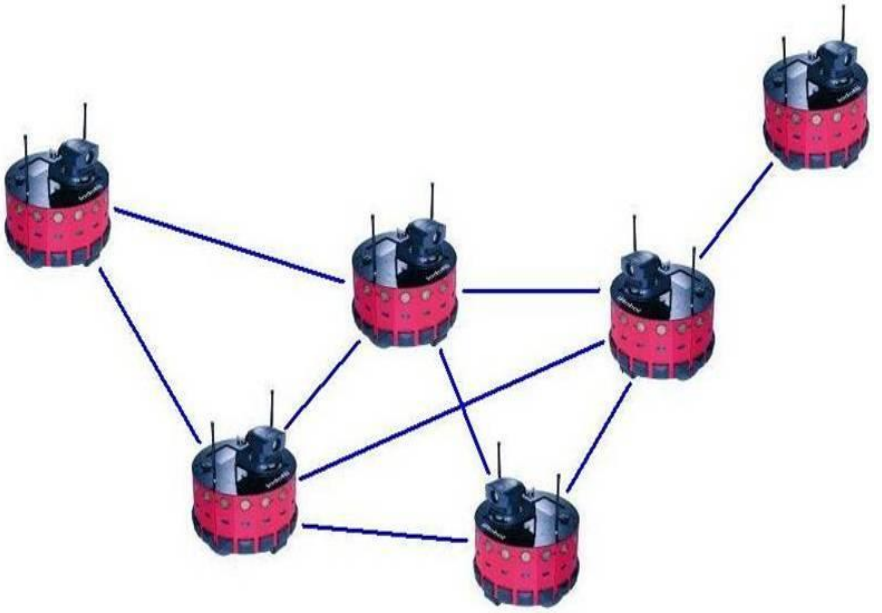
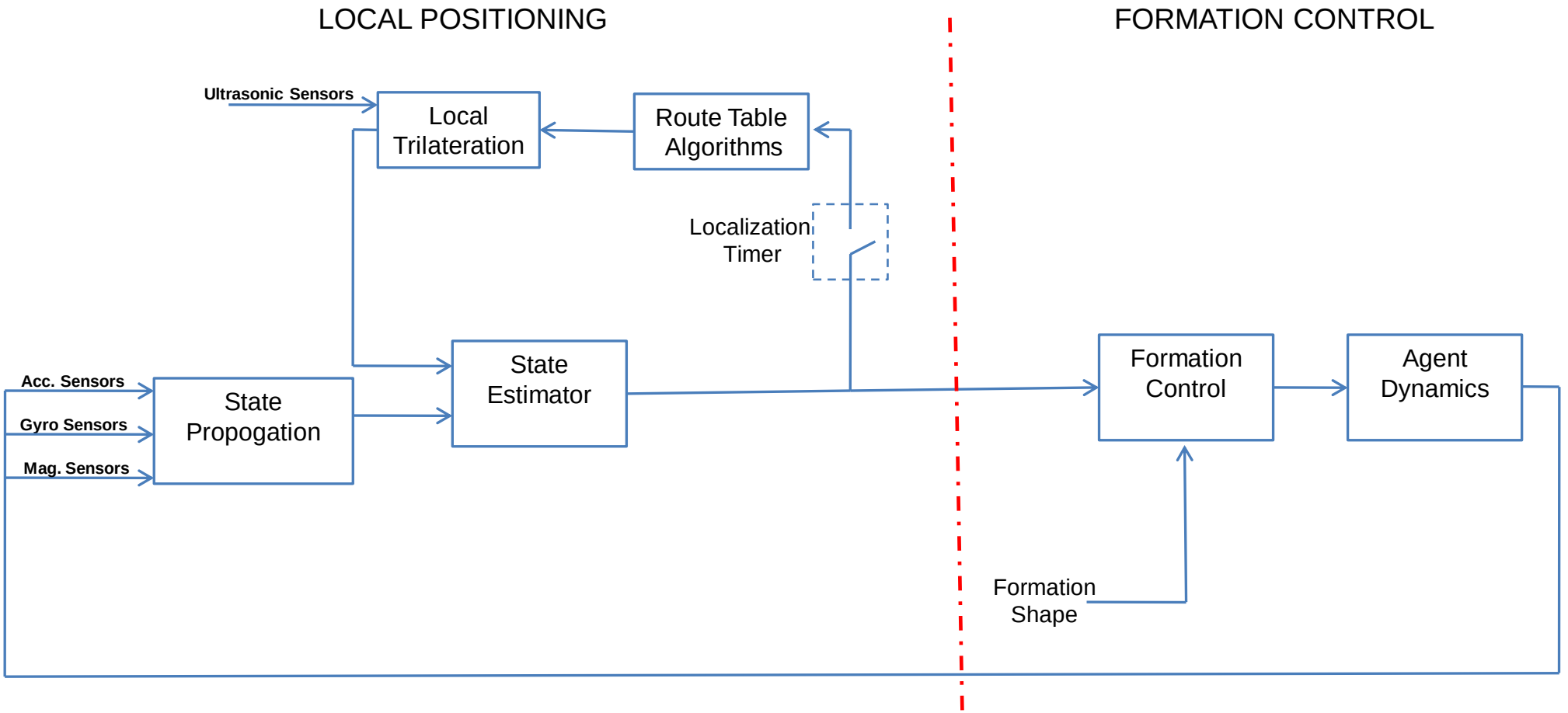
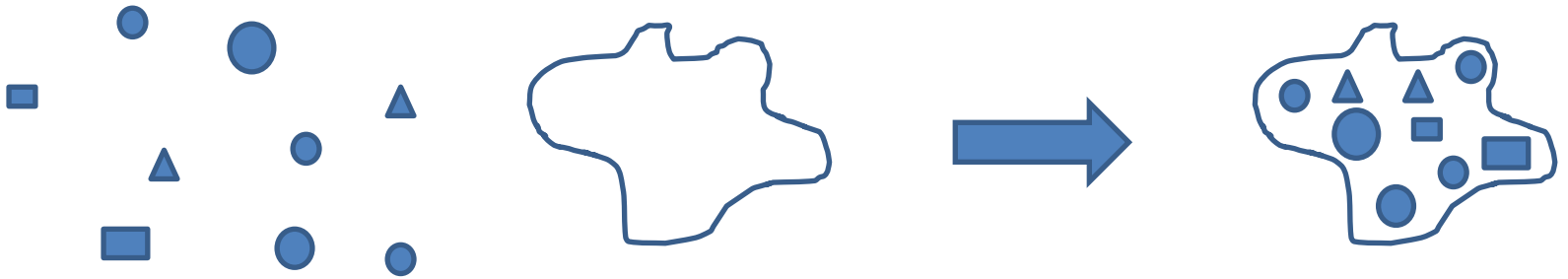
DYNAMIC FORMATION CONTROL WITH HETEROGENEOUS MOBILE ROBOTS



SYSTEM DESIGN





PROJECT BREAKDOWN STRUCTURE

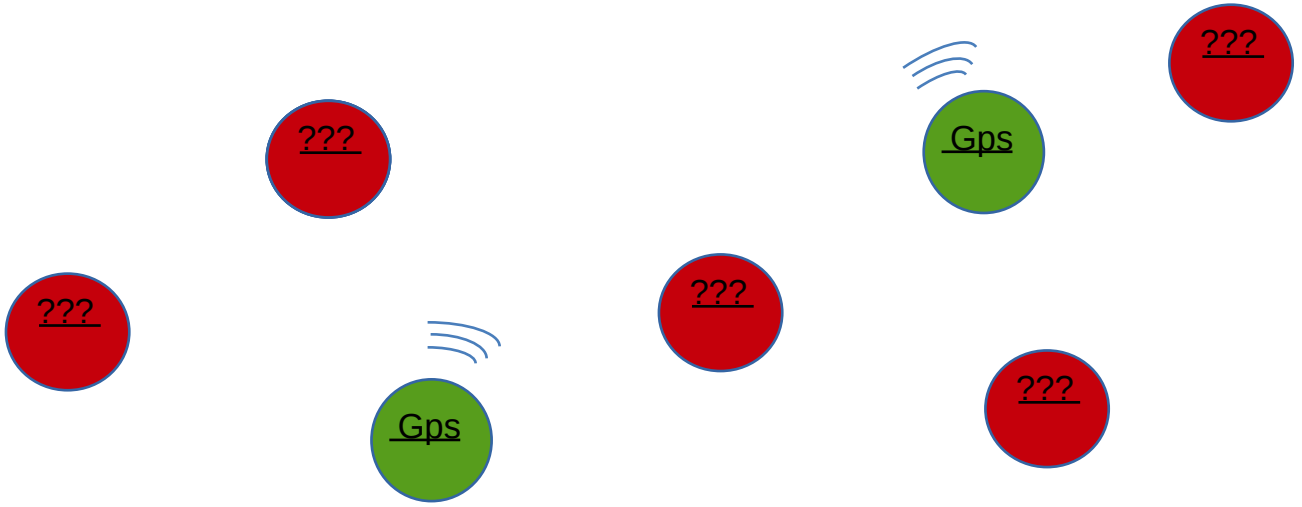
Two Main Problems related with project,

- Local Positioning System (LPS)
- Dynamic Formation Control

Local Positioning System(LPS)

It is assumed that only some of the agents have position sensors due to;

- Low cost implementation
- Power consumption issues

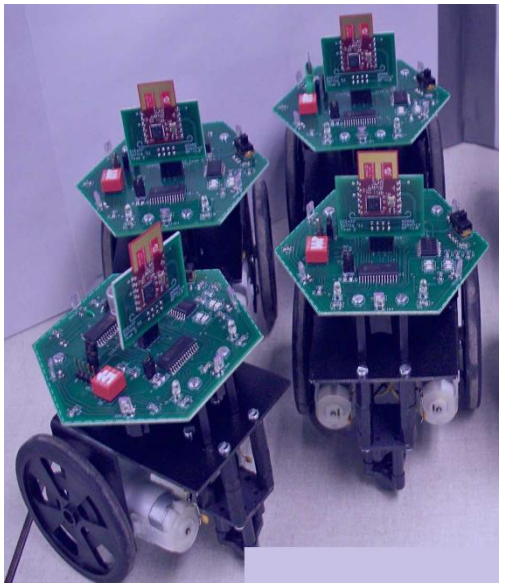


Local Positioning System(LPS)

It is needed to have a localisation solution to provide position data to the rest of the swarm, but there are some problems/restrictions on this problem.

Problem -1
Low sensor capabilities of agents

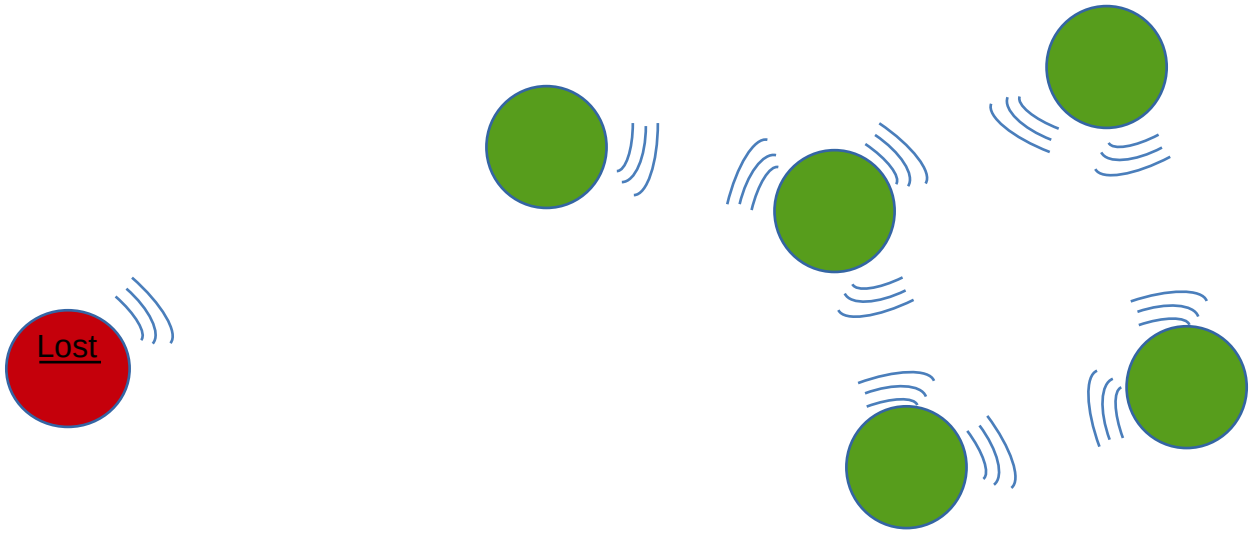
Due to cost effectiveness and power consumption issued all agents (except for positioning beacons)have low cost MEMS sensors like accelerometers gyroscopes, magnetometers and ultrasonic sensors.



Local Positioning System(LPS)

Problem -2
Weak Radio Links

Due to power consumption issues every agent has weak radios on board, so every agent has a radio link coverage for closest neighbors and data packets are limited with most critical data (e.g. agent ID, type and position) because of low bandwiths.



Local Positioning System(LPS)

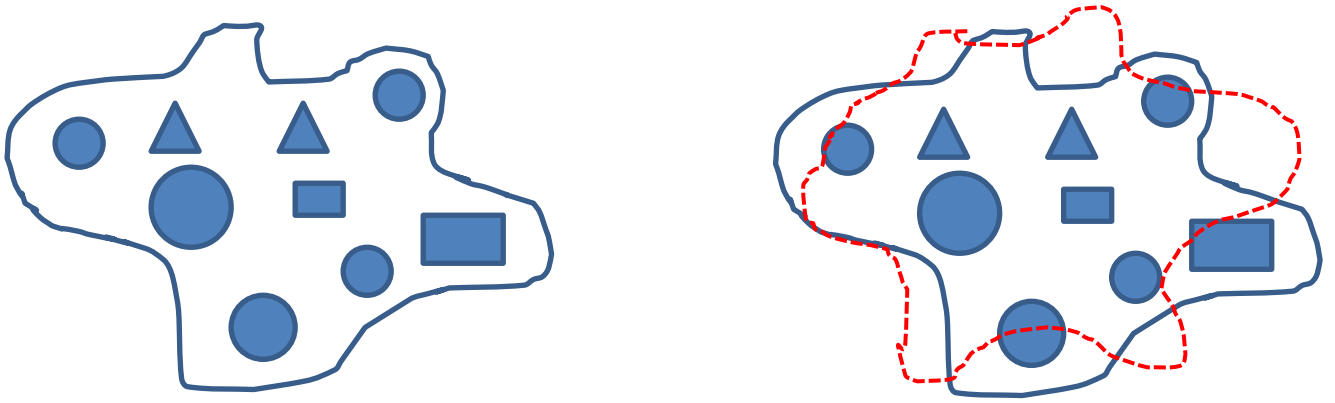
Problem -3
Low Computing Power

Every agent has low cost processors on board, it is not possible to implement complex algorithms and it is not possible to run localization process with high sampling rates.

Dynamic Formation Control

Problem -1
Complex Closed Contours

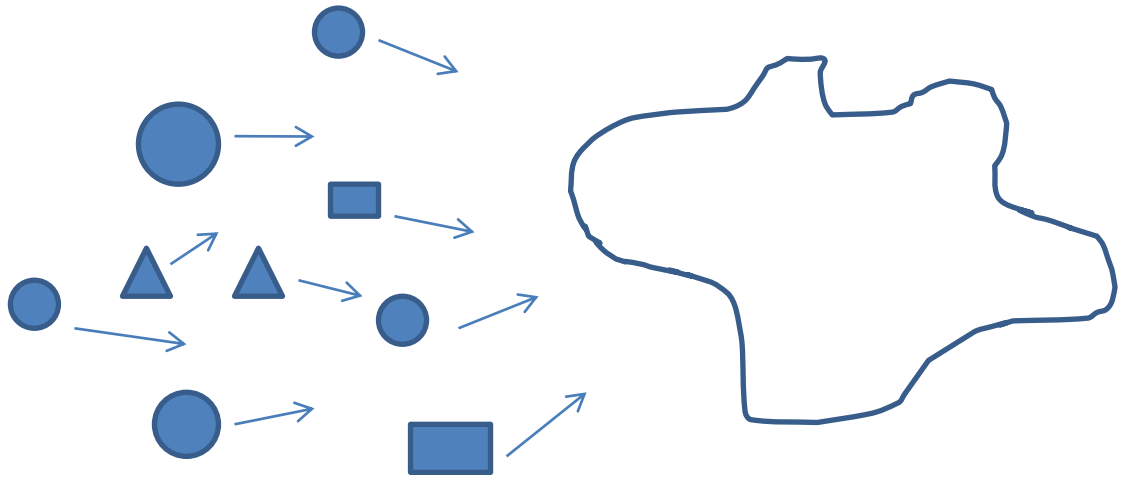
Formations shapes will be defined as closed curves with complex shapes and they cannot be identified analytically. On the other hand shapes will be changing dynamically during formation control.



Dynamic Formation Control

Problem -2
Decentalized Structure

There will be no central servers/root nodes to decide agents' individual positions to get the desired shape. Moreover, agents make their own position choices as unaware of the other agents' positions and choices.



•No decision maker for whole swarm

Dynamic Formation Control

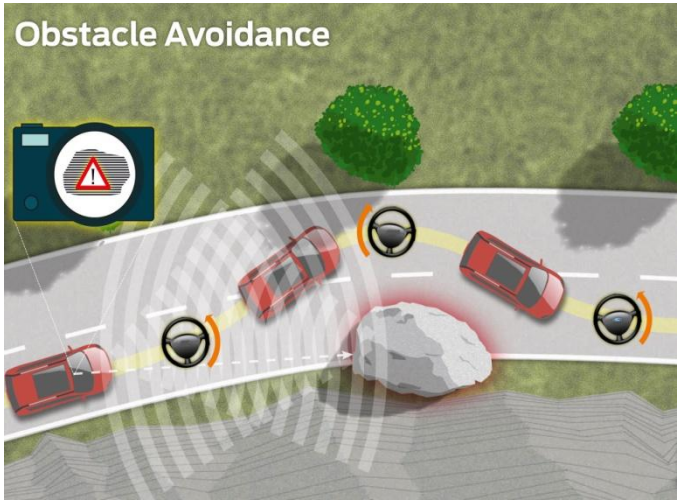
Problem -3
Heterogenous Robots with Different Dynamics

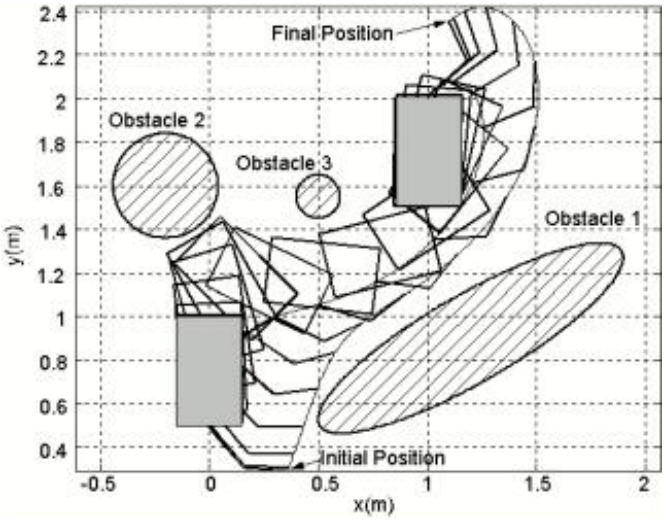
Agents will have different volumes and masses (no mass point particles) and they have different dynamics

Dynamic Formation Control

Problem -4
Collision Avoidance

Since the point mass approach for the agents are ignored, it is necessary to handle the collision events between agents. On the other side, the collision between the obstacles and the agents must be prevented.



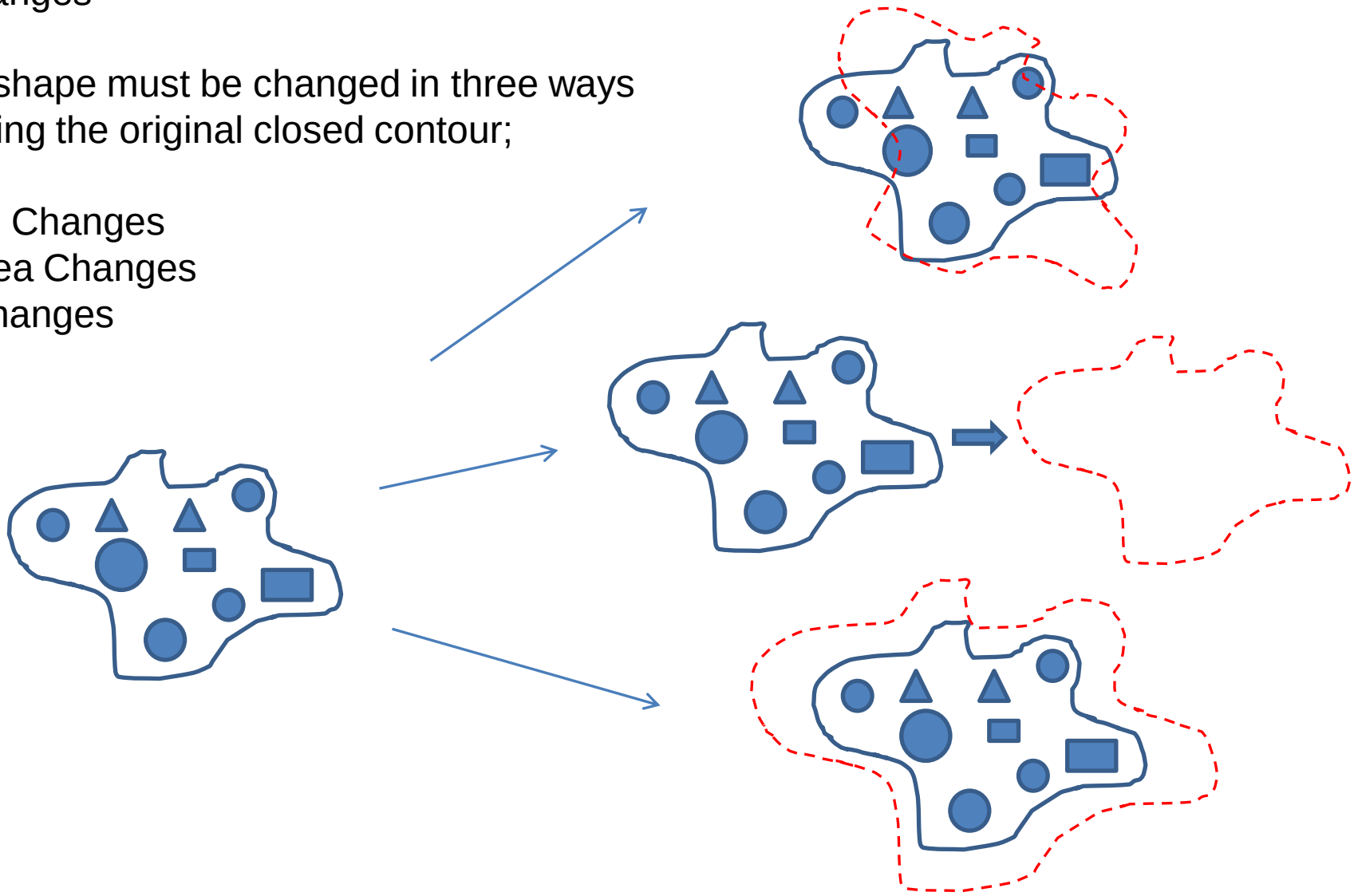


Dynamic Formation Control

Problem -5
Formation Changes

Formation shape must be changed in three ways while keeping the original closed contour;

1) Orientation Changes
2) Density/Area Changes
3) Position Changes



Dynamic Formation Control

Problem -6
Rugged Terrain Approach

Environment for the formation control must be a rough territorty. A 3D environment with some obstacles will be presented for simulations.

LPS System Design

Local positioning system is composed of two main parts.

Route Table Determination

This process determines the clusters around the Position beacons and provides the order for the Local trilateration process.

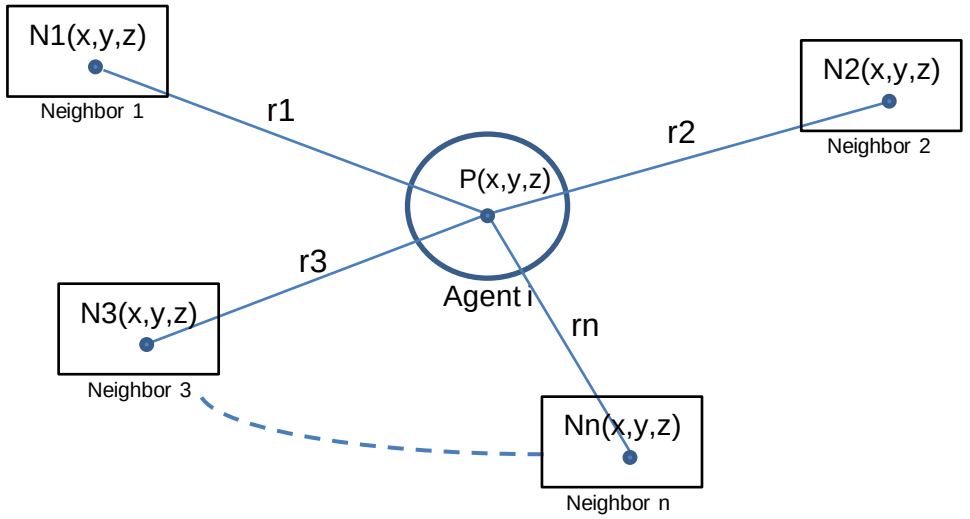
Local Trilateration

It provides position and translational velocity data To the agents which don't have position sensors

LPS System Design

Local trilateration process;

- Requires at least 3 neighbors
- Loops with low frequencies due to computational and power restrictions
- Handles lost agents (agents do not have three neighbors)



$A\vec{x} = \vec{b}$

LPS System Design

Solution of the position for agent (P(x,y,z)) can be reduced to a problem of;

$$A\vec{x} = \vec{b}$$

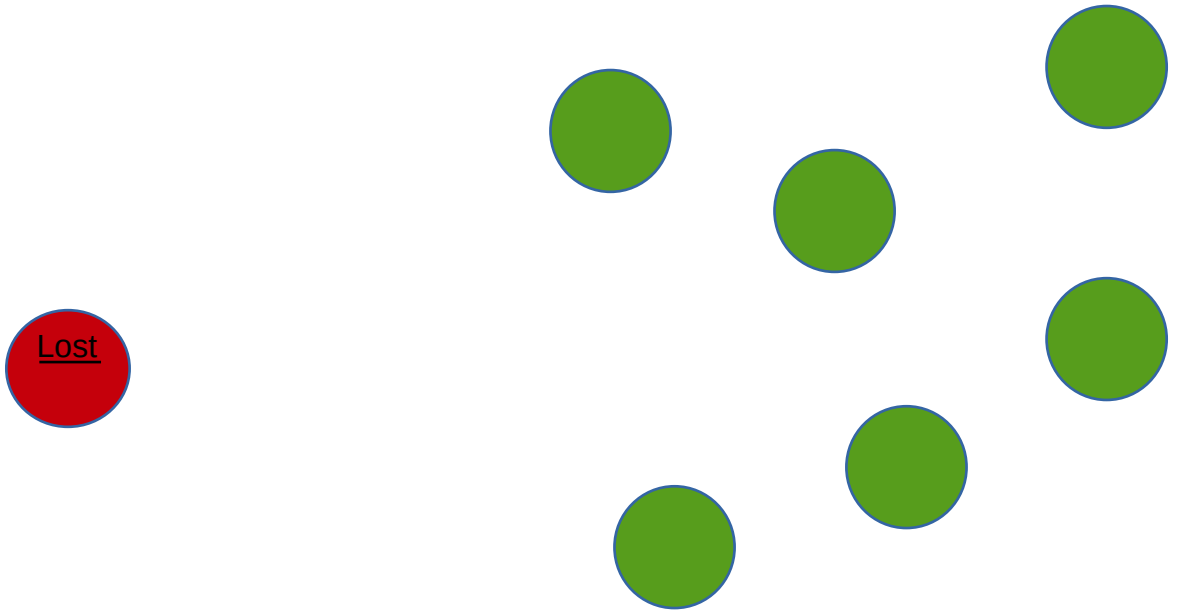
Since we have a A matrix with a dimension of (n-1) x 2, there are three options for The solution of the problem related with the condition of A matrix,

1) $\hat{x} = A^{-1}.b$, unique solution -> 3 neighbors and A is full column rank matrix
2) $\hat{x} = (A^T A)^{-1} A^T b$, minimum norm solution -> more neighbors and A is full column rank matrix
3) Find the minimum error/norm solution with nonlinear least squares method

LPS System Design

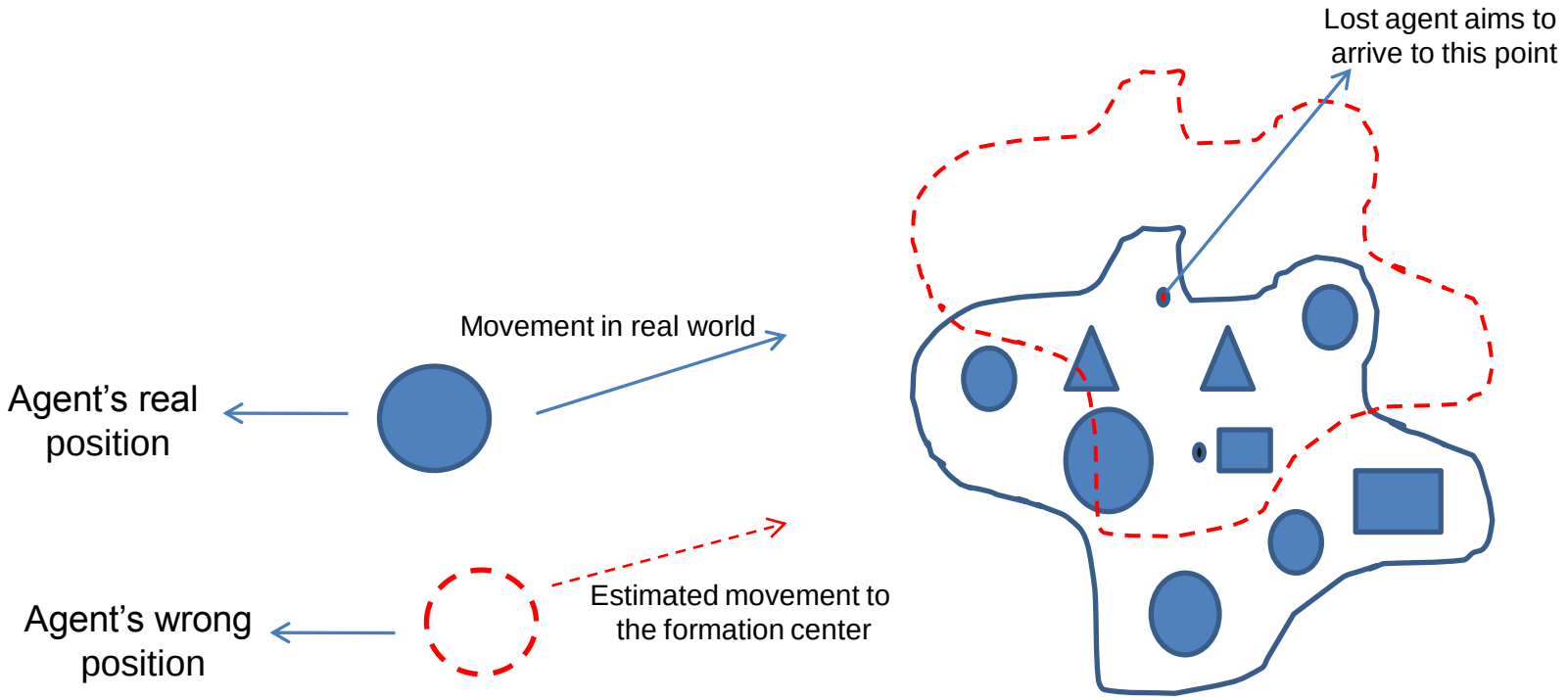
Lost agent handling rules,

- An agent is called ‘lost’ when it doesn’t have minimum 3 neighbors
- If an agent is lost it cannot enter the localization process
- If an agent is missing the localization process for 3-4 times(task dependent) then it must be directed to the formation shape center (Return to Home condition)



LPS System Design

Return to Home Approach



LPS System Design

Route Table Determination

- This process determines the clusters around position beacons and provides rank information for the agents which are in same clusters
- DSDV(Destination-Sequenced Distance Vector Routing Protocol) algorithms are used

3 no lu plot buraya gelecek

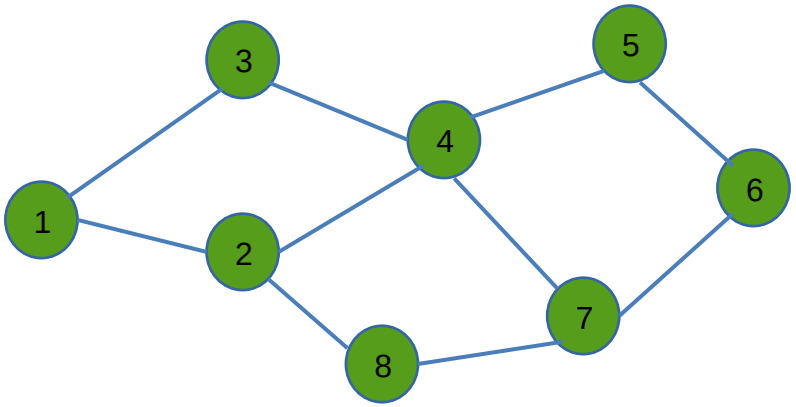
LPS System Design

DSDV

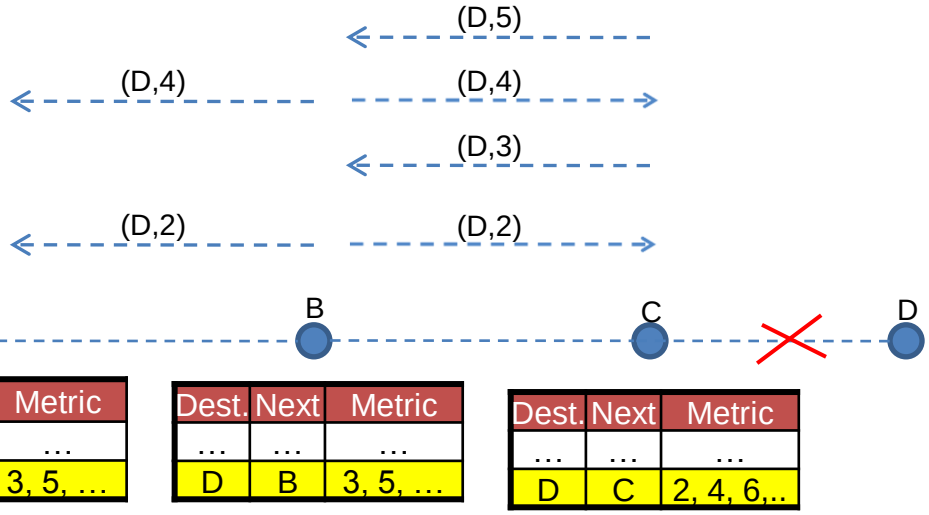
- DSDV is a table driven routing scheme based on Bellmam Ford algorithm
- Used generally in wireless mesh networks and ad-hoc mobile networks
- Solves routing loop problem in Bellman Ford algorithm

Route table for agent 2

Destination	Next Hop	Metric	Dest. Seq. No
1	1	1	123
3	3	1	516
4	4	1	212
5	4	2	168
6	8	3	372
7	8	2	432



Routing Loop Problem



LPS System Design

DSDV Rules for Localization Problem

- Metric value for the route table must be counts for hops
- Agents must decide to join the cluster of position agent with minimum metric value
- This approach minimizes the error rate for the positions of agents which are relatively far away from the beacons.
- Localization process must be done with increasing order of counts for hops in a cluster

2 no lu plot buraya gelecek