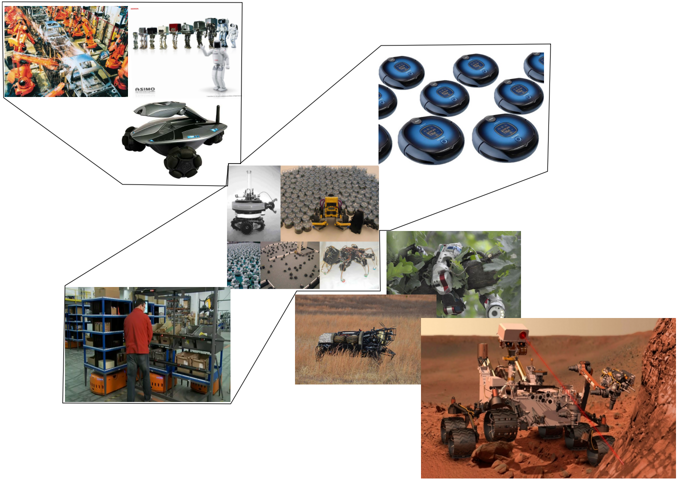
On Maintaining Connectivity of a Colony of Autonomous Explorer Mobile Robots

Jonathan Matías Palma Olate[1] and Cristian Duran-Faundez[2]

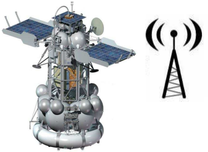
Departamento de Ingeniería Eléctrica y Electrónica
Universidad del Bío-Bío, Concepción, Chile.

October 21, 2014

Robotics.

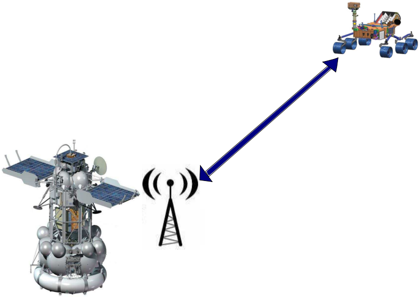


Methods to maintain a communication link of explorer robot.



Methods to maintain a communication link of explorer robot.

A) Direct Communication.



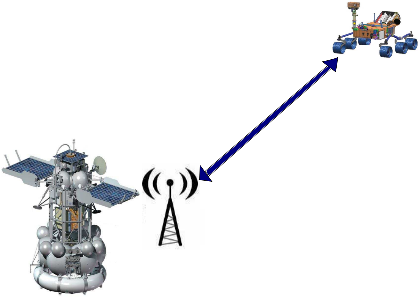
Methods to maintain a communication link of explorer robot.

A) Direct Communication.

-Limited coverage Transmit.

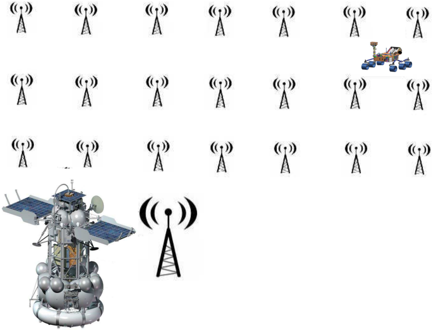
-Unique link, not robust.

-High power transmission over long distances.



Methods to maintain a communication link of explorer robot.

B)Communication with Static Router.



Methodsto maintain a communication link of explorer robot.

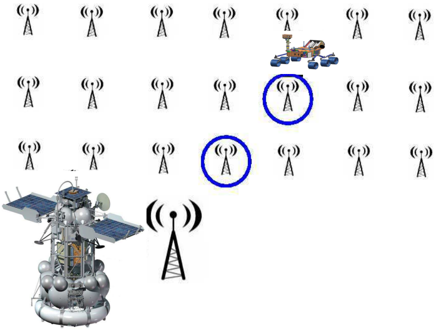
B)Communication with Static Router.

-Previous infrastructure.

-High cost of implementation and maintenance.

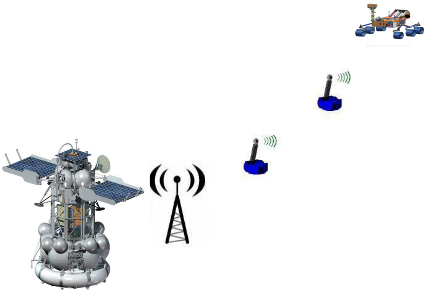
-Robustness to the failure of a unit.

-A subset of the total units the network participateing actively in the link communication.



Methods to maintain a communication link of explorer robot **(Proposal)**.

C)Communication using Mobile Router.



Methods to maintain a communication link of explorer robot **(Proposal)**.

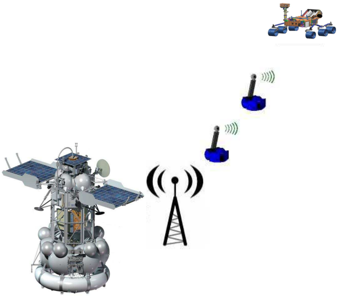
C)Communication using Mobile Router.

-Dynamic deployment.

-Minimize energy and cost.

-Design flexibility.

-High level of technical complexity in implementation. today.



Methods to maintain a communication link of explorer robot **(Proposal)**.

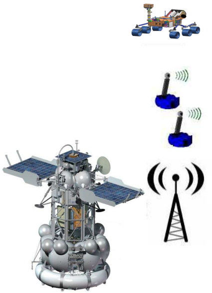
C)Communication using Mobile Router.

-Dynamic deployment.

-Minimize energy and cost.

-Design flexibility.

-High level of technical complexity in implementation. today.



Tethering

Tethering is the robot task of following a mobile agent (human, robot, etc.), with all the different required capabilities to it, in order to provide network connectivity (Zickler and Veloso 2010).

The reference we propose includes the following kind of nodes:

-A set Base Station : Gateways (GW).

-A set Explorer Robot : Targets (TG).

-A set Router Robots : Gangway of data (GG).

Network Topology Options

Link type to use?
Model network of interest simple-link. Figure Network Topology link green.

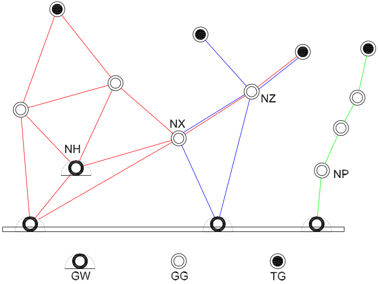


Figure: Network Topology.

This scenario entails a set of sub-problems, including:

- -Definition of a link quality metric.
- -Drive router robots to optimal positions to forward data packets.
- -Minimizing the amount of robot routers maintaining global performance.
- -Addressing robustness. Which involves methods to deal with communication errors and incidentals such as robot failures.
- -Sharing tasks. To provide ways to make robots share some tasks, e.g., to make a router robot take other router's job allowing the second one to go to the base station for recharge or maintenance.

Definition of Link Quality Metric.

Metric quality standard of wireless communication.

- Packet Loss Rate PLR.
- link quality indicator LQI.
- Received Signal Strength Indicator RSSI.

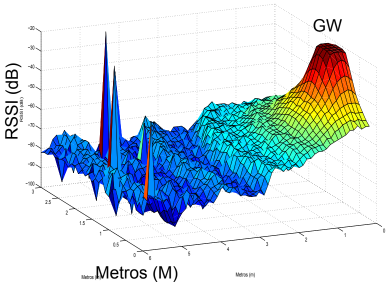


Figure: Example RSSI vs Distance

Optimal point (PO) to ideal model.

PO Geometric: midpoint between the line formed superior and inferior units.

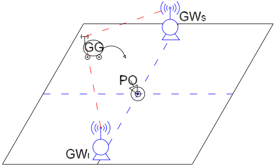


Figure: Network: two GW and on GG

PO based on the RSSI: coordinate where the RSSI is equal and also the sum of them is maximum

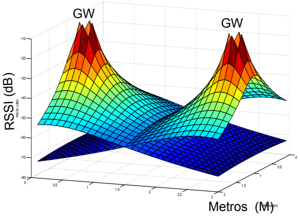


Figure: RSSI to *GW* the network.

Orientation Method. Indicator *MIn Dif*.

Let us define *VS* and *VI* as the communication links between a router robot and the neighboring node closest to the explorer and the base station. Obteniandiendo las relaciones.

$$Dif_a = |RSSI_{VS} - RSSI_{VI}|$$

$$Dif_d = \frac{RSSI_{VS} - RSSI_{VI}}{Dif_a}$$

Dif_a is relevant because *PO* difference of RSSI to *PO* it zero. Status indicators can be defined. Decrease Dif_a, which is calculated as:

$$MIn_{Dif} = \begin{cases} 1 & \text{if } Dif_a(k) - Dif_a(k-1) < 0 \\ 0 & \text{otherwise} \end{cases}$$

Orientation Method. Indicators *Max* and *Min* link Vx.

The VX it VL farthest link and VC closer link.
Decreases of RSSI values for a communication link VX, can be calculated as:

$$Min_{VC} = \begin{cases} 1 & \text{if } RSSI_{VX}(k) - RSSI_{VX}(k-1) < 0 \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

Increase of RSSI values for a communication link VX, which is defined as:

$$Max_{VL} = \begin{cases} 1 & \text{if } RSSI_{VX}(k) - RSSI_{VX}(k-1) > 0 \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

Actions. Discrete displacements.

The Figure presents the eight possible actions $[A_1, A_2, ...A_8]$. It also implements a ninth action A_9 that is return.

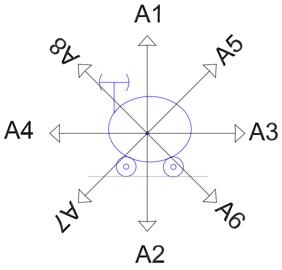


Figure: Actions.

States based on the indicators Min_{Dif}, Min_{VC} and Max_{VL}.

Are defined the state S to function. The Indicators are binaries $i \in [1, 2.....2^3]$, having eight possible states

$$S_i = \varphi(Min_{Dif}, Min_{VC}, Max_{VL})$$

State compact SS**:** Are defined the state compact SS_1 and SS_2.

.

$SS_1 = \varphi(Min_{Dif}, Min_{VC}, Max_{VL});\ Min_{Dif} = Min_{VC} = Max_{VL} = 1$
$SS_2 =$otherwise

Algorithm Proposal

Objectives.

-Design an algorithm that achieves converge to units in the vicinity of the optimum point (PO), maximizing both of RSSI values link.
-Design an algorithm that orientation method depends only on current and past RSSI values, does not consider additional information of the environment.
-Evaluate the performance of the algorithm in a simulation problem Tethering.

Algorithm, Heuristics based to Q-learning.

The action selection is performed by using a Q-learning-based vector $Q(SS \times A_i)$. We adopted as learning coefficient $\alpha = 0.5$, and we assign a reward $+1$.

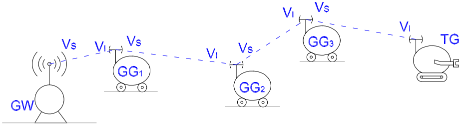
For the proposed model there are four transitions $(SS_{k-1} \rightarrow SS_k)$, i.e. transitions of passing from an state SS_{k-1} in previous iteration $k-1$ to the current state SS_k. These transitions are: $(SS_1 \rightarrow SS_2)$, $(SS_2 \rightarrow SS_2)$, $(SS_1 \rightarrow SS_1)$, and $(SS_2 \rightarrow SS_2)$.

Require: RSSI captures
Require: Calculation of goals and categorizations for states $SS(k)$ and $SS(k-1)$.

if $SS_{k-1} = SS_1$ **and** $SS_k = SS_2$ **then**
    return $A9$
end if
if $SS_{k-1} = SS_2$ **and** $SS_k = SS_2$ **then**
    return random A_i; $i \in [1, 8]$
end if
$A_c = MaxA_cInQ(Q, SS)$
$Q(SS, A_c) \leftarrow (1-\alpha)Q(SS, A_c) + \alpha[r(SS, A_c) + \lambda \max_{A \in A_{s'}} Q(s', A')]$
return A_c

Evaluation performance the algorithm.

Evaluation of the proposed algorithm was by the mean and standard deviation of a set of simulations to $k = 500$ iterations. The Network used it the figure.



Model to Maintaining Connectivity the Robot Explore.

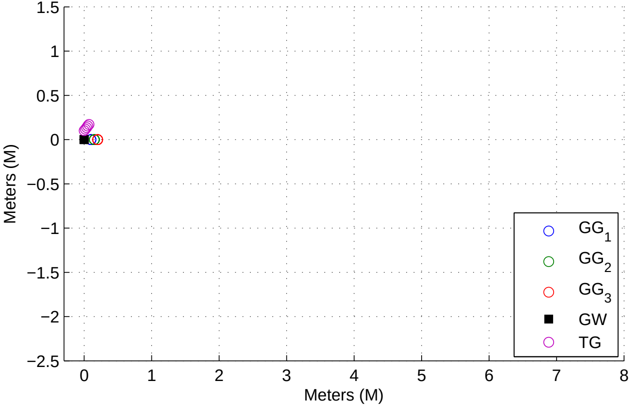
The graphs are the mean and standard deviation for 1000 simulations.

Description of the Simulation, parameters an values.

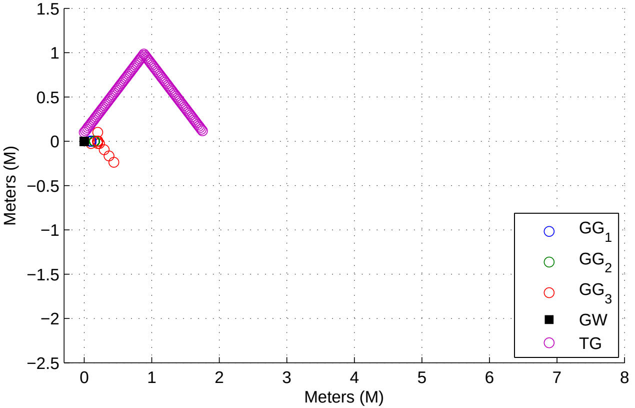
parameters	: **values**
k	: 500.
V_{pi}	: $\begin{bmatrix}0,0 & 0,-0.15 & 0,-0.3 & 0,-0.45 & 0,0.1\end{bmatrix}$.
$\Delta Paso$	: 0.1(m).
Model RSSI	: log normal shadowing.
$M \times P$	: 20.
State	: SS_1 y SS_2. .
Actions	: A_1 A_2 A_3, A_3, A_5 A_6 A_7, A_8 and A_9.
Reward	: $SS_1 = 1$ y $SS_2 = -1$.
Learning Rates	: $\gamma = 0.5$ y $\alpha = 0.5$.
TG mov	: zig zag

Simulation

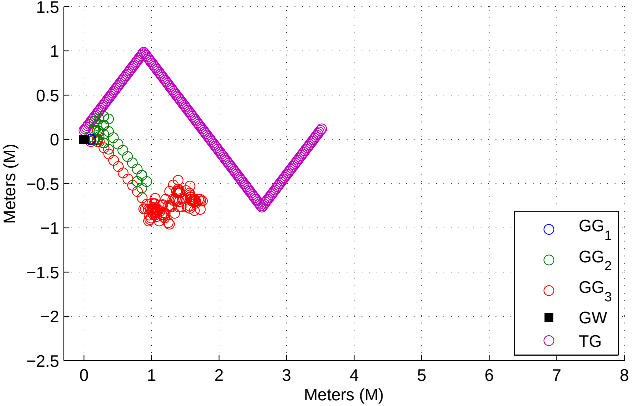
Positions of units, center of mass for $k = 5$ iterations.



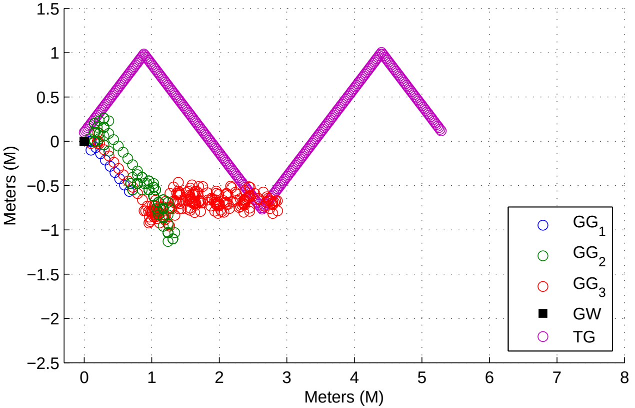
Positions of units, center of mass for $k = 100$ iterations.



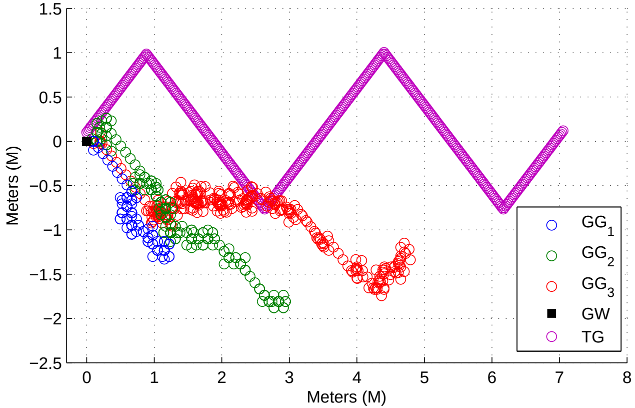
Positions of units, center of mass for $k = 200$ iterations.



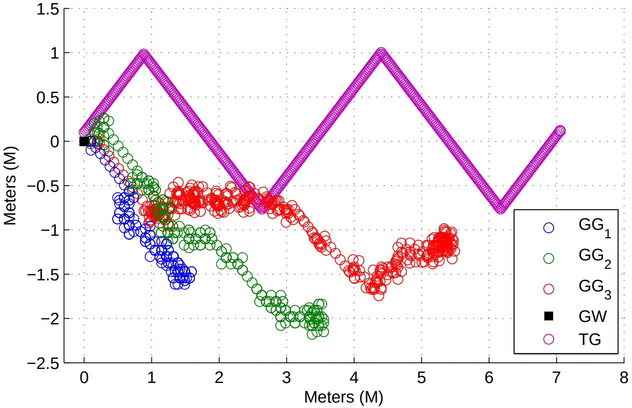
Positions of units, center of mass for $k = 300$ iterations.



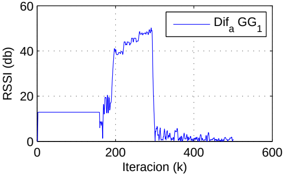
Positions of units, center of mass for $k = 400$ iterations.



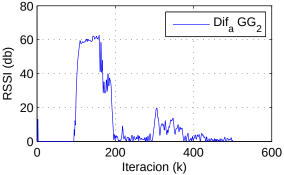
Positions of units, center of mass for $k = 500$ iterations.



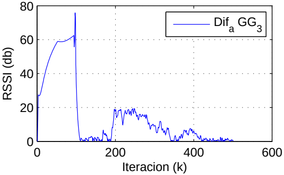
Mean the *Dif*$_a$ and Standard Deviation.



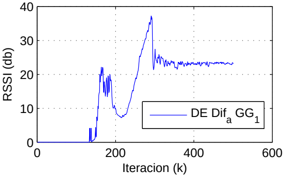
((a)) Mean *Dif*$_a$ GG1.



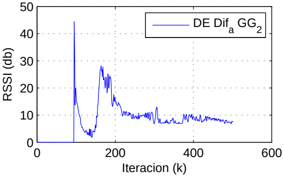
((b)) Mean *Dif*$_a$ GG2.



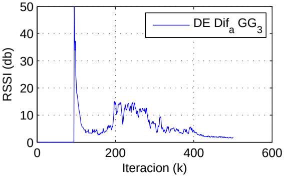
((c)) Mean *Dif*$_a$ GG3.



((d)) S deviation *Dif*$_a$ GG1.

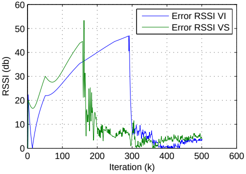


((e)) S deviation *Dif*$_a$ GG2.

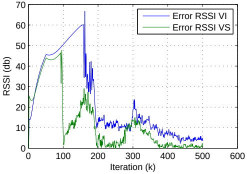


((f)) S deviation *Dif*$_a$ GG3.

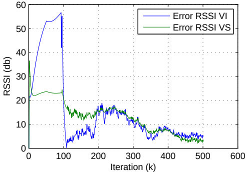
Mean the error of RSSI and Standard Deviation .



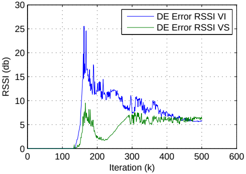
((g)) Error RSSI, GG1.



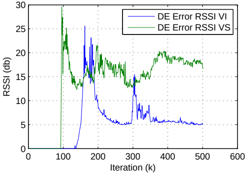
((h)) Error RSSI, GG2.



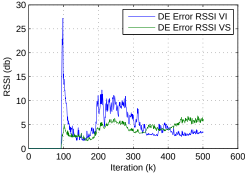
((i)) Error RSSI, GG3.



((j)) S deviation error GG1.



((k)) S deviation error GG2.



((l)) S deviation error GG3.

Conclusion and Comments.

This paper describes a kind of application for problem and sub-problems communication whit explorer robots and a base station using a colony of autonomous router robots.

The model to single link the algorithm based to RSSI for maintaining communication it feasible.

This heuristic is used to select the next action to perform by a robotic router, combining simple decisions with a Q-learning-based decision process. Simulation results over 1000 repetitions of a simulation scheme shows good performance of the algorithm to make converge router robots to near-optimal positions, considering the simulated models restrictions

Acknowledgment.

This work was supported by the Research Department of the University of Bio-Bio (Project DIUBB 121910 2/R).

End.