Modelling variable communication signal strength for experiments with multi-robot teams

Tsvetan Zhivkov[1] and Elizabeth I Sklar[1,2]
[1]Dept of Engineering, King's College London, Strand, WC2R 2LS, UK
[2]Lincoln Institute for Agri-food Technology, University of Lincoln, LN6 7TS, UK
tsvetan.zhivkov@kcl.ac.uk, esklar@lincoln.ac.uk

Abstract

Reliable communication is a critical factor for ensuring robust performance of multi-robot teams. A selection of results are presented here comparing the impact of poor network quality on team performance under several conditions. Two different processes for emulating degraded network signal strength are compared in a physical environment: modelled signal degradation (*MSD*), approximated according to increasing distance from a connected network node (i.e. robot), versus effective signal degradation (*ESD*). The results of both signal strength processes exhibit similar trends, demonstrating that *ESD* in a physical environment can be modelled relatively well using *MSD*.

Approach

The focus of this research is on a physical environment that does not have network infrastructure to support communication. We have developed the Multi-Robot Communication (*MRComm*) framework to perform multi-robot experiments to analyse communication performance [6]. The contributions presented here can be separated into two parts:

1. modelling various aspects of network quality (*MRComm*); and
2. controlling robot behaviour in response to changes in the network quality (i.e. Leader-Follower behaviour).

The *MRComm* framework uses Robot Operating System (ROS) [2] as well as the *FKIE* [1] package.

- An Ad-Hoc (*AH*) network is established at the start of an experiment and all robots communicate peer-to-peer.
- Signal strength between robots is either estimated by employing the modelled signal degradation (*MSD*) threshold function or using the effective signal degradation (*ESD*).
  - ▹ ***MSD*** is modelled using two SVR models, for both direct and obstructed line-of-sight signal strength. The resulting estimate of the signal strength is plotted in Figure 3.
  - ▹ ***ESD*** is a novel process that queries all robots in the *AH* network at a frequency of 2 Hz obtaining the actual signal strength from each one. The actual signal strength is plotted in Figure 3.
- Network perturbation is applied in the form of dropping a certain percentage of messages (i.e. 0%, 25%, 50% and 75%), denoted simulated packet-loss (*SPL*) [4].
- The response to the network parameters is denoted as Leader-Follower (*LF*), which is our novel high-level multi-robot behaviour that is communication-aware [5]. Robots initialised with this behaviour will respond to poor signal strength as a result of moving further away from their neighbours, by grouping the robot team and will attempt to continue communicating in the event of message dropping. However, there is also a baseline response, denoted as Non-responsive Behaviour (*NB*), which is not communication-aware and simply enables robots to complete their assigned tasks regardless of communication.

Experiments

Five experiments were conducted using;

- 3 physical turtlebot2 robots starting nearby each other, in a "clustered" configuration
- 7 observational tasks (defined in [3])

All experiments are run using *AH* network and a particular configuration as shown in Figure 1.

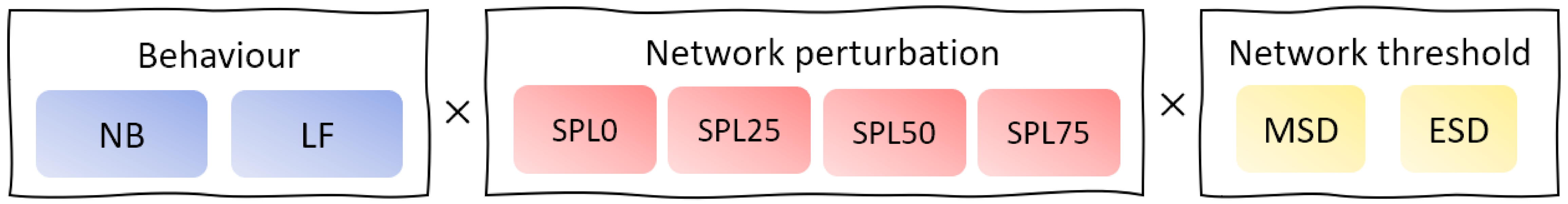

Figure 1: Experiment Configuration

Environment and Parameters

Figure 2 shows degrading signal strength between two robots in direct line-of-sight as distance increases. Each point is the mean obtained from 20 consecutive readings at a particular distance. As can be noted by the layout of the indoor office environment and the corresponding tasks, it is improbable for robots to continuously be in direct line-of-sight of each other. Furthermore, as the distance increases to 9 m, the signal strength exhibited drops below -50 dBm, which we consider a poor signal. To make our research problem more tractable, the communication cutoff point for the *AH* network is therefore ≈ 9 m.

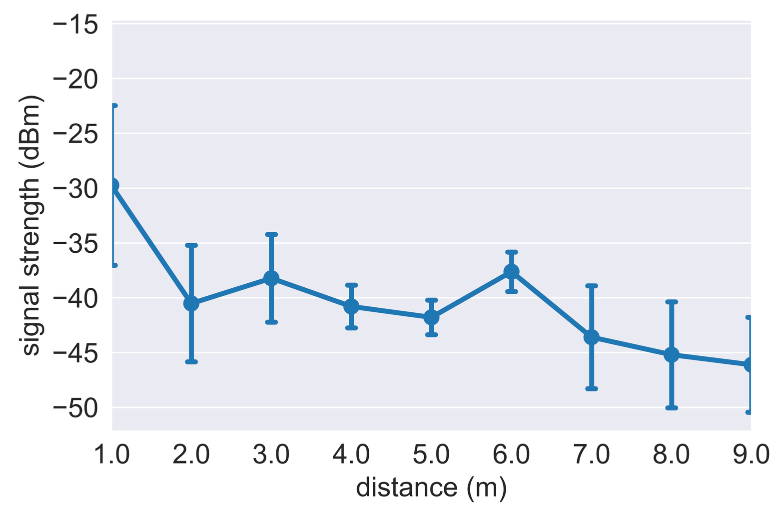

Figure 2: Indoor office direct line-of-sight signal strength vs. distance

Figure 3 shows the physical office environment used for experiments. The robots, which are depicted as circles on the map, are colour coded to represent which task (i.e. crosses on the map) is assigned to them at the start of a mission.

Figure 4 shows the mean *MSD* and *ESD* signal strength over a range of time t, measured in seconds from when experiments start at $t_0 = 0$ up until $t = 150$ s (i.e. the first 150 seconds of each experiment). To improve comparability between *MSD* and *ESD* the results were obtained from experiments using only the same configuration.

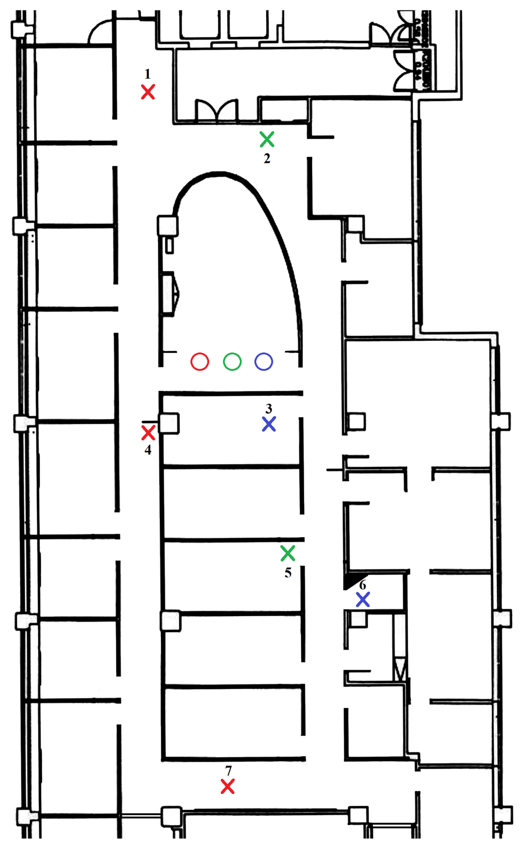

Figure 3: Indoor office environment circles represent robots and crosses tasks

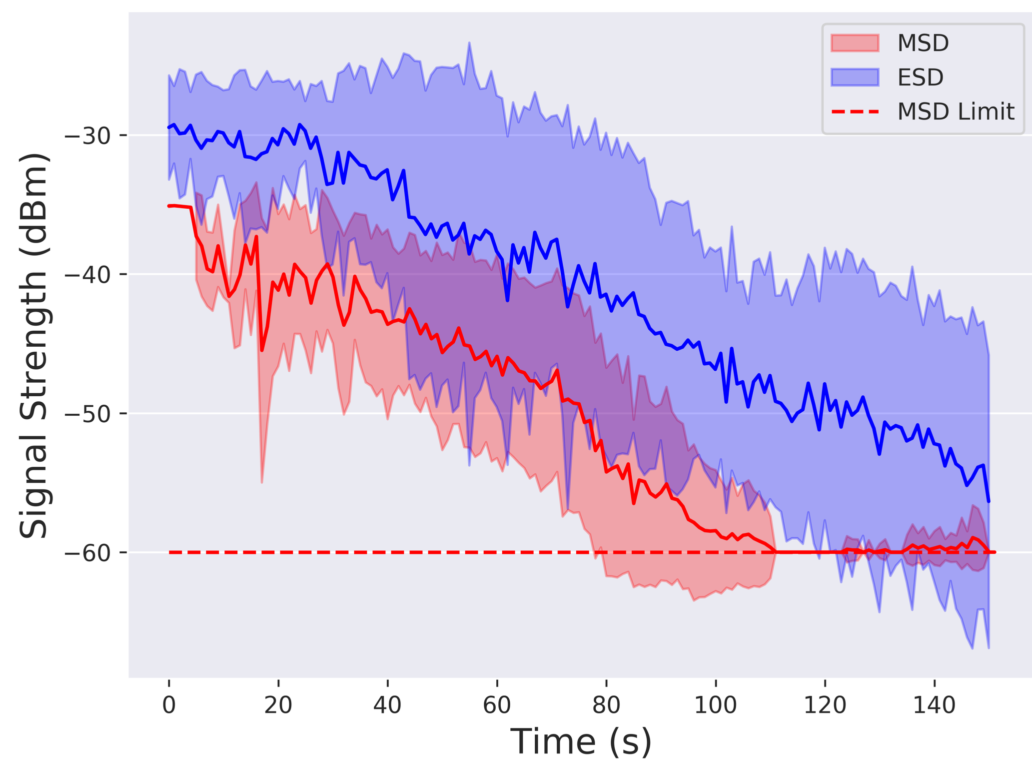

Figure 4: The average signal strength of MSD and ESD representing the first 150 seconds of experiments

Results

Figures 5 and 6 show a sample of experiment configurations and the number of tasks that failed to be communicated per robot in the team. The results for this performance metric showed that *no* robot using *NB* successfully communicated *all* their task status messages. However, the results reveal that robots using the *LF* behaviour managed to always communicate *all* their task status messages.

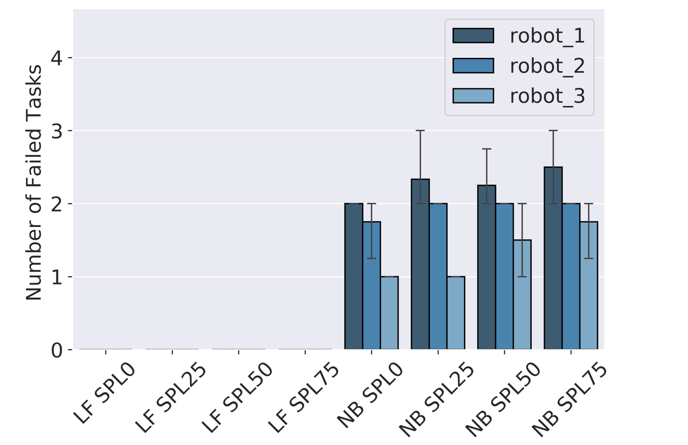

Figure 5: Average failed tasks per robot for MSD

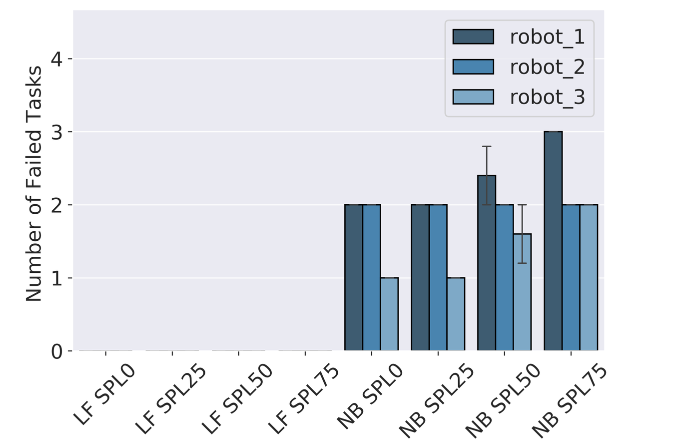

Figure 6: Average failed tasks per robot for ESD

Summary

The results presented here show that communication of shared messages was successfully carried out on a physical multi-robot team using the novel *LF* behaviour. Furthermore, we observe that the *MSD* parameter has a similar signal strength trend to the *ESD* parameter. Our objective of having a behaviour capable of reacting and mitigating common network issues has been achieved. In future work we will focus on optimising and expanding the capability of the behaviour to deal with more challenging tasks and environments.

References

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