Wireless Communication in High-traffic Environments

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1. Background

The Northern Bites are a small, student-led team of computer scientists from Bowdoin College. The team programs humanoid robots to compete in the RoboCup Standard Platform League, a worldwide robotic soccer competition. These robots are autonomous - in game, they make their own decisions without any input from humans.

Standard Platform League rules do not allow modification of robot hardware, and all teams are required to use the same robot - the NAO robot, manufactured by Aldebaran Robotics. NAO hardware includes an integrated wireless network interface and antenna.

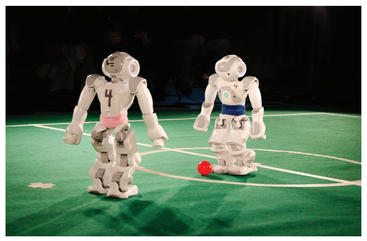

Figure 1:
Two NAO robots face off at a Northern Bites demonstration in October.

2. Purpose

To play soccer well, the Northern Bites' robots are highly dependent on wireless networking. Robots use data sent from other robots on the team over the wireless network to calculate their own position and determine their role in the game.

At yearly international competitions, wireless conditions are often suboptimal. Interference from many different wireless devices and networks (*Figure 2*) on a small number of channels causes loss of wireless range, long data travel times and data that is simply "lost." It is thus very difficult to play soccer effectively when the team needs to the most.

The NAO's default wireless connection manager, *connman*, is simple to use but handles "noisy" wireless environments poorly. The goal of this research is to replace *connman* with a more stable and customizable alternative.

3. Methods

To determine the effects of any changes to wireless networking code, diagnostic tools were first needed. An initial part of this research involved developing a graphical data inspector to capture and display robot location information sent over the wireless network. The amount, and timeliness, of data transferred has a direct impact on the accuracy of location information, which is displayed (*Figure 4*) in the tool.

By performing on-site tests and talking to other teams at the 2012 RoboCup World Cup this summer in Mexico City, it was determined that the likely cause of wireless issues was the NAO's default wireless management daemon. This daemon, *connman*, would disconnect from the preferred wireless network and fail to reconnect for long periods of time in high-traffic environments. The daemon did not allow customization to change these behaviors, so switching to a more configurable wireless daemon was necessary.

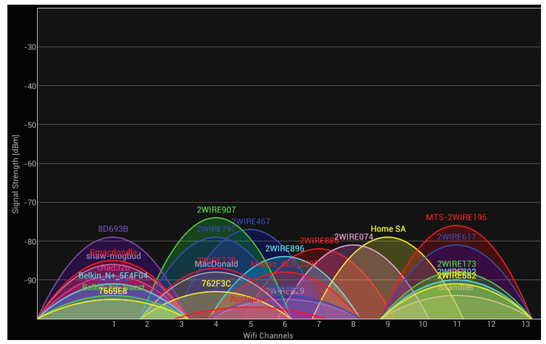

Figure 2:
A high-traffic wireless environment. Many different access points operate on overlapping channels, resulting in low perceived signal levels (-dBm) for all networks. Image courtesy of thessdreview.com

The next phase of this research was to remove *connman* from all of the Northern Bites' robots and install a replacement. The most suitable option was *wpa-supplicant*, a highly customizable and open-source daemon used on many embedded Linux systems. Removing and replacing *connman* involved modification of critical NAO system files, with a substantial potential of rendering the robot unable to communicate (necessitating a factory reset).

5. Results

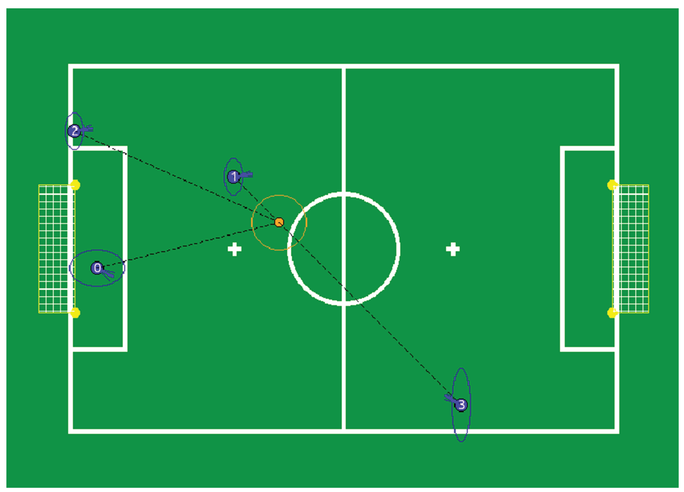

Figure 1:
The data visualization tool developed as a part of this research shows a team of robots localizing well despite the effects of network congestion.

The implementation of *wpa-supplicant* on Northern Bites robots was highly successful. After tailoring the daemon's settings (*Figure 3*) to meet the needs of the high-traffic environment, the Northern Bites were able to move from a "playing blind" scenario to one in which, if traffic interference overwhelmed a NAO and caused it to lose connection to a target wireless network, the robot would re-acquire the network connection and re-join the team in a maximum of thirty seconds. This improvement occured entirely without boosting transmission power (altering signal-to-noise ratio) or removing any interference present. This result was thus a great success.

Improvements in wireless reliability were reflected in the increased accuracy of the displayed location model (*Figure 4*). With more robots connected and actively sending data over the wireless network, a more full picture of the team's relative locations could be developed. Increased communication of this model between robots following the introduction of the improved wireless system resulted in the robots playing noticeably better.

Figure 3:
wpa-supplicant offers a high level of customization.

6. Conclusions/Future Work

Replacing *connman* with *wpa-supplicant* significantly increased the effectiveness of the Northern Bites in high-traffic wireless environments. This strategy improved network connectivity without altering physical hardware, and has made the task of managing the NAO's wireless networking significantly more customizable and powerful. This research had a definite positive effect on our performance at the 2012 RoboCup World Cup in Mexico City, and should continue to aid the team in future competitions.

The Northern Bites expect to soon be moving to a new communications system which implements multicasting, the simultaneous broadcast of data to several clients. The connection management framework developed through this research will need to be extensively tested and possibly modified to ensure it is compatible with a multicast system.

7. Acknowledgments

I would like to thank the team members of the Northern Bites and Professor Eric Chown for making this research possible.

This project was funded by the Maine Space Grant Consortium. Bowdoin College is an affiliate of the Maine Space Consortium.