Investigation of track performance with non-ideal communication channels

Adapt_MFR V3.2.10 software release notes and test results

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Abstract

DRDC Ottawa has contracted C-CORE for software support services related to target tracking and coordinated radar resource management (RRM) using an Adaptive Multi-Function Radar simulator (Adapt_MFR).

During this work, some effort was spent revisiting and validating results for a single radar.

The main purpose of this work was to evaluate the target detection and tracking performance of networked radars subject to non-ideal communication channels effected by transmission time delays and data loss.

The experimental results show that as the communication channel time delay increased, track completeness, track occupancy, and frame time decreased. Results also show that as data error loss increases, less track observations are sent to the tracker resulting in lower track completeness, track occupancy, and frame times.

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1 Introduction

DRDC Ottawa has contracted C-CORE for software support services related to target tracking and coordinated radar resource management (RRM) using an Adaptive Multi-Function Radar simulator (Adapt_MFR).

Some effort was spent revisiting and validating results from a previous version of Adapt_MFR for a single radar. The software was updated with bug fixes and other important functionality to support new metrics calculations.

The main purpose of this task is to evaluate the detection and tracking performance of networked radars when communication channels are non-ideal. This includes error-free but time delayed reception of data and partial reception of data due to bit errors.

This report summarizes the work done under Task 6 which includes the implementation of non-ideal communication channels, the addition of miscellaneous functionality, bug fixes and testing, simulation, and analysis of results.

2 Validation of results from Adapt_MFR v3.2.5 for a single radar

This section describes the work done to revisit and validate results from version 3.2.5 of Adapt_MFR for a single radar. Prior to these tests, the software was updated with bug fixes and other important functionality to support some new metrics calculations.

2.1 Simulation setup

The scenario files used to test the software were based on previous files but were tweaked to better position the targets in the radar field of view. The plane view of the scenarios (scenario_no_birds_2014c and scenario_no_birds_2014d_152) simulated in this task are shown in Figure 1 and Figure 2. In this scenario, a single-radar system with 52 and 152 targets were modeled. The radar was positioned at [0,0] and is shown in the figures circled by a blue ring. The initial position of each target is indicated by a red triangle. The 152 target scenario was generated by making two copies of the first 52 targets and shifting them in azimuth and offsetting them in time.

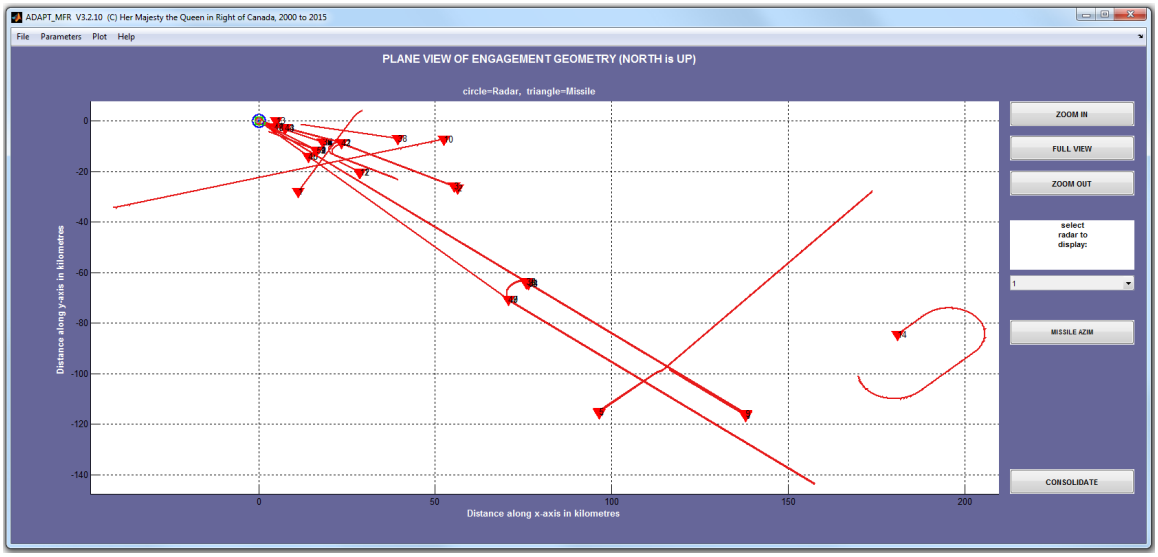


Figure 1: *Scenario plane view, 52 targets*

Some of the radar system parameters used are listed in Table 1.

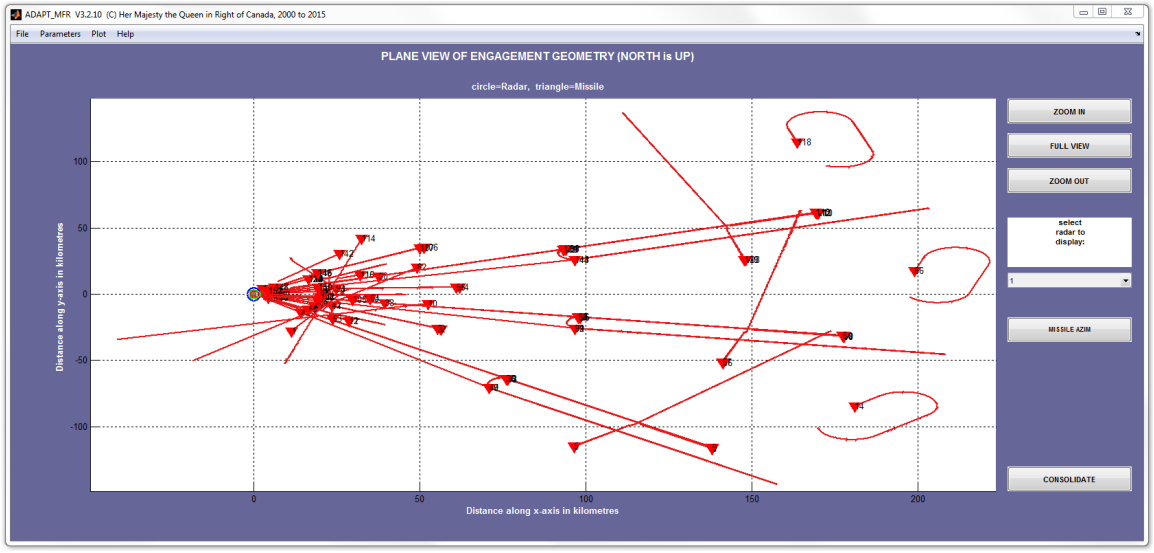


Figure 2: *Scenario plane view, 152 targets*

Table 1: *Adapt_MFR parameters used in simulations*

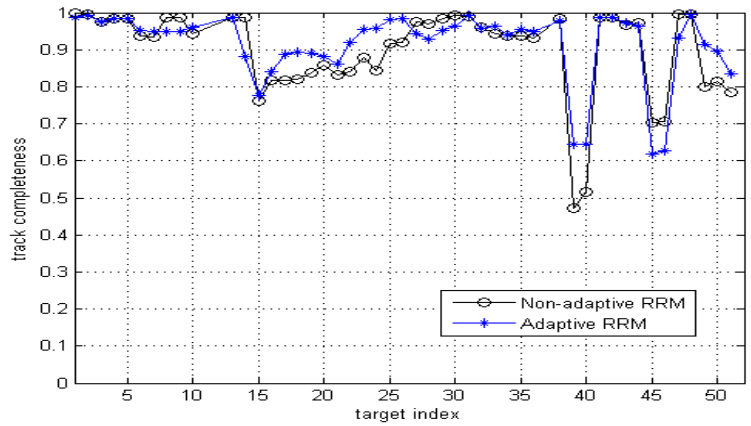
Radar position:	Azimuth boresite*: 90 degrees Elevation boresite*: 0 degrees Antenna height: 30 m
Track update rates:	Target priority ≥ 0.7: update rate min:max = 0.25 : 2 s Target priority > 0.7 & < 0.3: update rate min:max = 3 : 4 s Target priority ≤ 0.3: tracks not scheduled; rely on detection & collateral track beams
Scenario duration:	600 s

* 0 degrees is North, CW is positive direction.

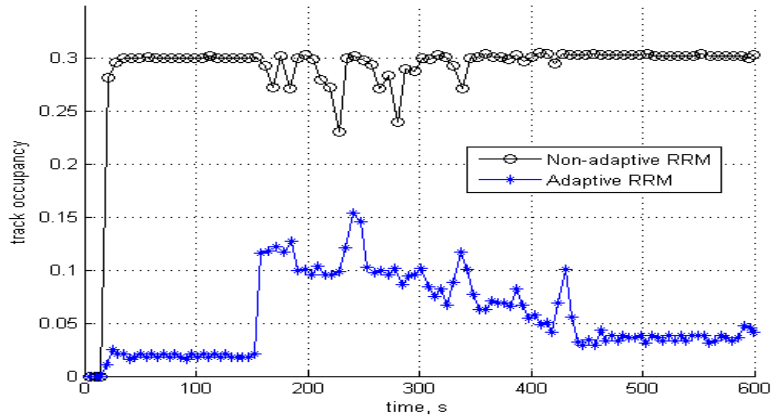
2.2 Results

Figures 3 and 4 show the advantage of RRM with adaptive time balancing. The track occupancy and frame times are lower for adaptive scenarios with little effect on track completeness. In the 152 target scenario the advantage is lessened. Figure 3 shows the track completeness, track occupancy, and frame times for the 52 target scenario. Figure 4 shows the track completeness, track occupancy, and frame times for the 152 target scenario.

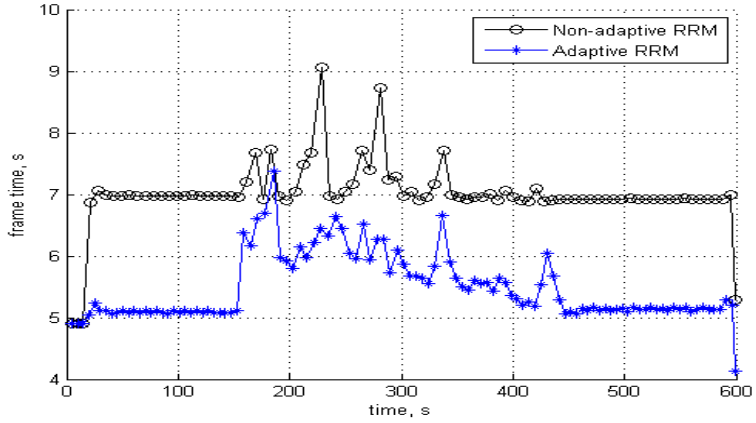
Figures 5 and 6 were generated to validate track priority settings and track update rates. Figure 5 shows the target range, azimuth and radial velocity of target 1. These are shown to relate their effect on track priority and update rates. Figure 6 shows the desired and actual track update intervals and priority for target 1. After 150 seconds, the target makes a turn which causes the priority to slowly decrease to a change-over point where the track update interval setting increases.



(a)

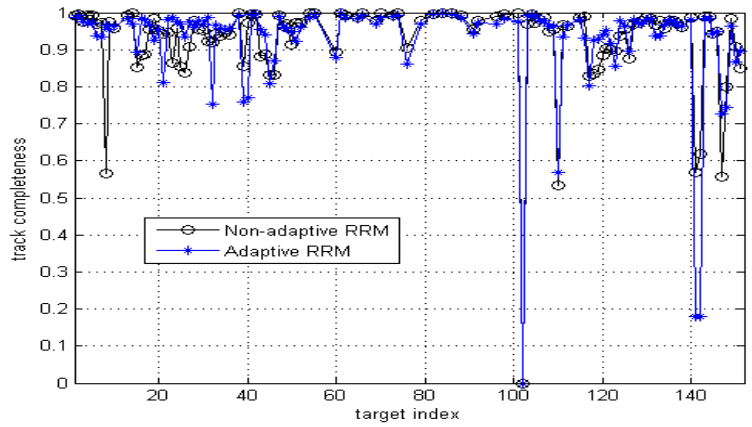


(b)

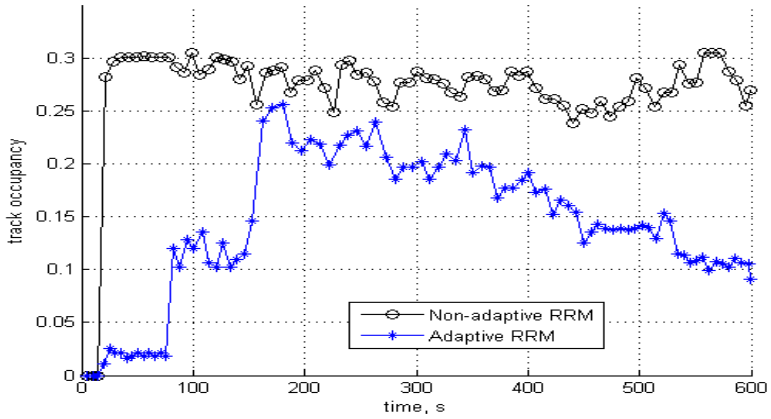


(c)

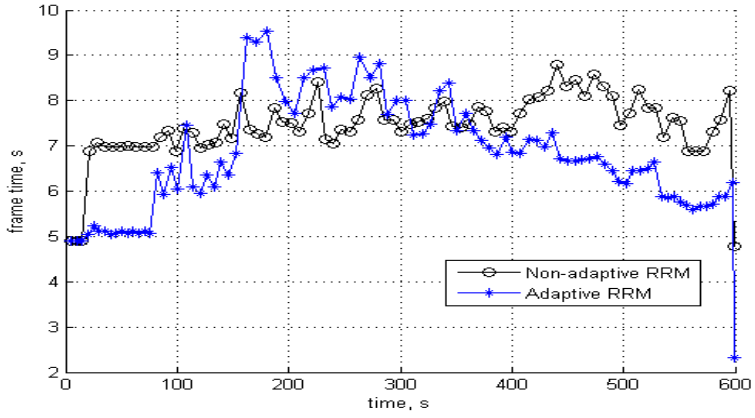
Figure 3: *Scenario 52 targets. (a) Track completeness. (b) Track occupancy. (c) Frame time.*



(a)

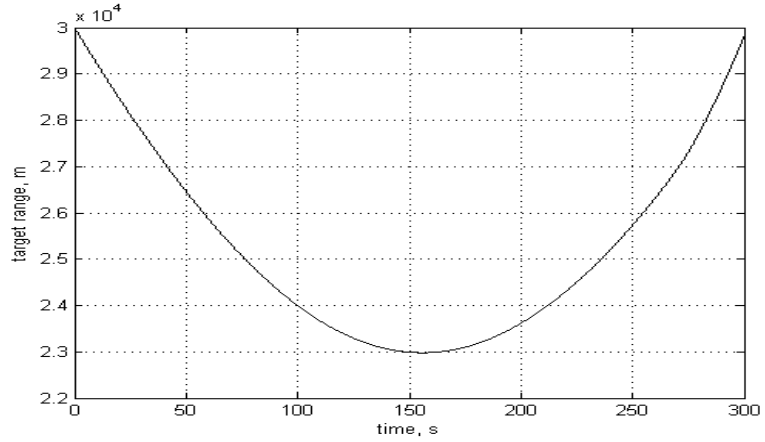


(b)

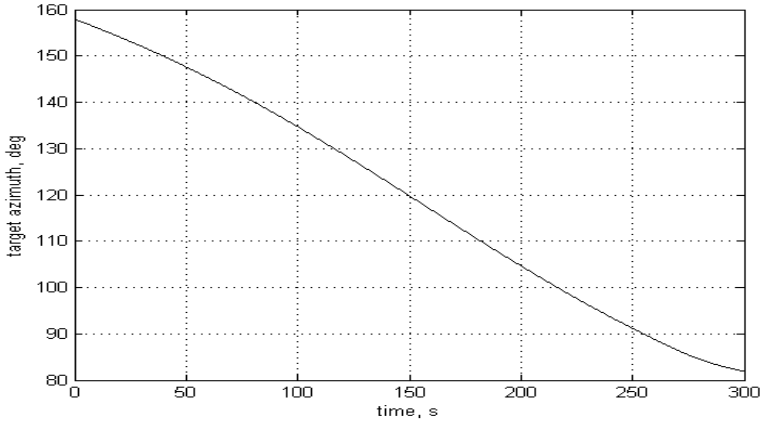


(c)

Figure 4: *Scenario 152 targets. (a) Track completeness. (b) Track occupancy. (c) Frame time.*



(a)



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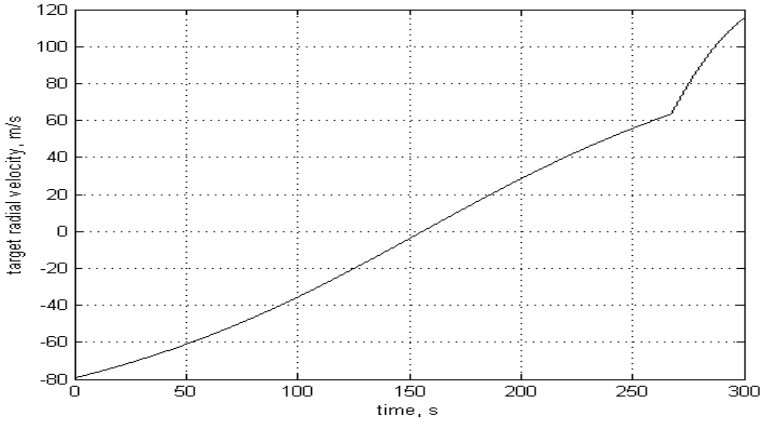
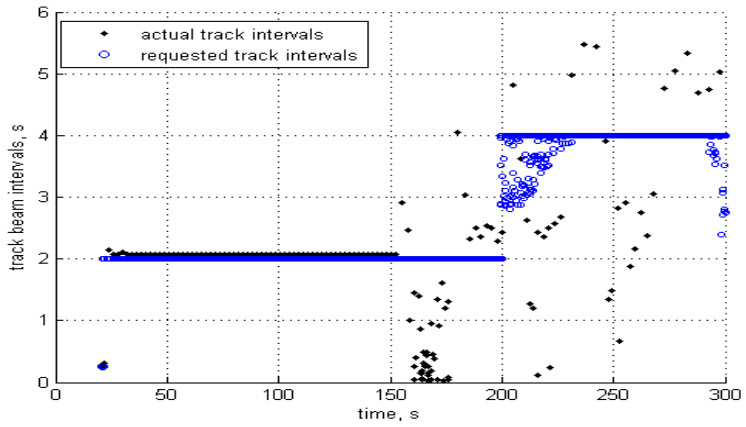
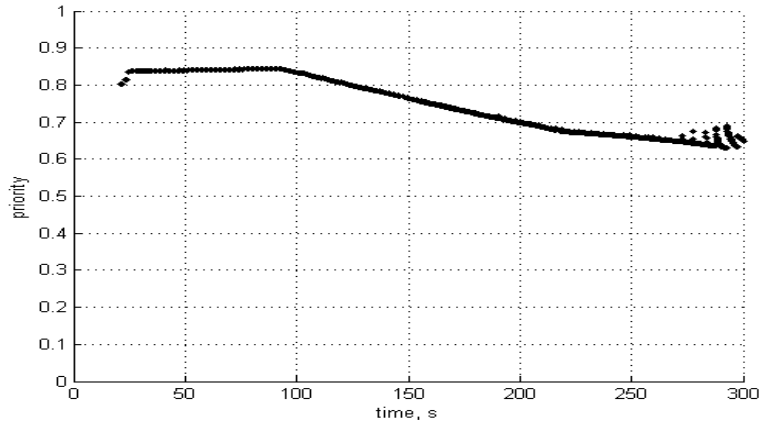


(c)

Figure 5: *Target 1. (a) Range vs. time. (b) Azimuth vs. time. (c) Radial velocity vs. time.*



(a)



(b)

Figure 6: *Target 1. (a) Track update intervals vs. time. (b) Priority vs. time.*

3 New functionality for networked radars

3.1 Non-ideal communication channels

In this task, the functionality to simulate the effects of non-ideal communication channels was added.

Adapt_MFR can now simulate:

- error free communication with data latency; and/or
- partial reception of data due to communication bit errors.

To accomplish this functionality, several modifications to the software were made. These modifications include:

- an algorithm used to delay track observations from being sent to the tracker based on a random portion of maximum communication latency set by the user;
- logic to allow delay only if the communication channel type is set accordingly and/or the simulations uses RRM; and
- an algorithm used to deny track observations from being sent to the tracker if the bit error associated with the current observation exceeds the bit error rate threshold *(*(BER_threshold)) set by the user. The bit errors are currently randomly generated. Actual track observation values are not currently modified with bit errors (but will be in future work).

Files affected:

.\GUI\cbLoadParams.m - lines 69
.\GUI\cbSaveParams.m - lines 27 & 55
.\Main\add_false_alarms.m - lines 210, 308, 364, & 473
.\Main\centroid_detections.m - lines 48, 59, 73, 84, 115, 144, 178, 347, 367, 393, 413, 479, & 523
.\Main\communication_channel_control.m - lines 77:104 & 133
.\Main\set_scheduler.m - lines 98, 143, & 151
.\Main\update_scheduler.m - lines 103, 162, 247, 291, & 391
.\Main\adaptmfr_run.m - lines 158:171, several between 1055:1857, 2629, & 3184

Last Modification Date:
Feb 2015

3.2 Testing non-ideal communications

This section describes the work done to test the non-ideal communication channel modifications. Tests were done with the current version (3.2.10) of Adapt_MFR.

3.2.1 Simulation setups

The scenario file scenario_no_birds_2014c (Figure 1) was again used to test the non-ideal communication channel modifications.

The track update scheduling used by the current version of Adapt_MFR differs from that of the older version and is shown in Table 2.

The communication channel was set to always be available for the experiments. The RRM type was set to type 2 but only one radar was utilized. This was in order to validate the operation and show the effects of delay or denial of tracks being sent to the tracker on track completeness, track occupancy and frame time, without multi-radar effects. In standard operation, multiple radars should be used as communication errors arise from transmission problems between radars and the new functionality was added to simulate this.

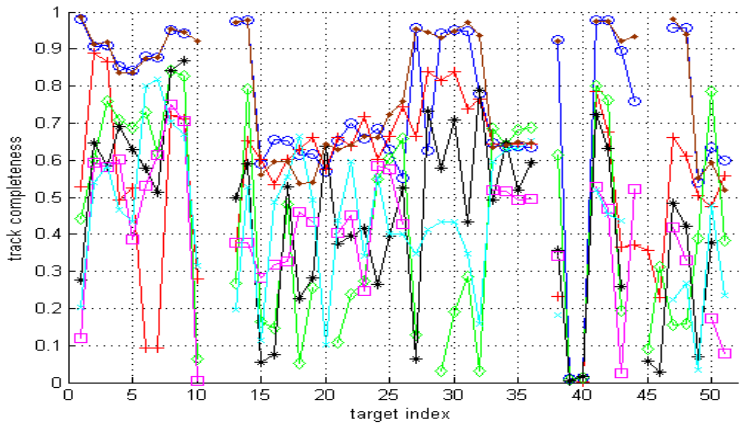
Table 2: *Adapt_MFR parameters used in simulations*

Track update rates:	Target priority ≥ 0.75: update rate = 1.5 s
	Target priority < 0.75: update rate = 3 s

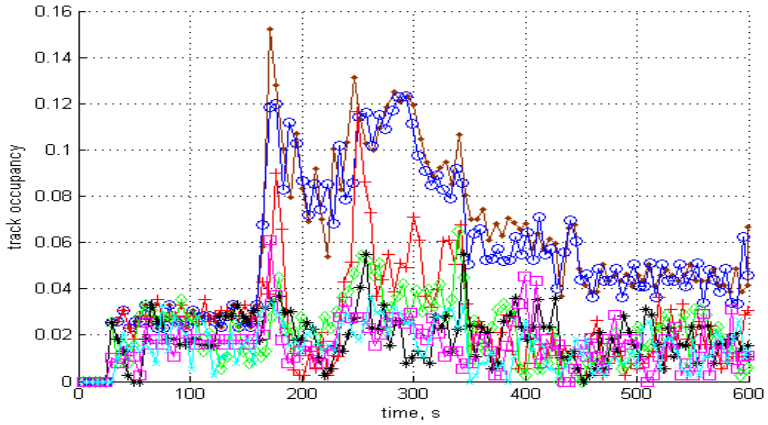
3.2.2 Results

Figure 7 shows the track completeness, track occupancy, and frame times for the 52 target scenario with various transmission time delay settings. The results show that as communication channel time delay increases, track completeness, occupancy and frame time decreases.

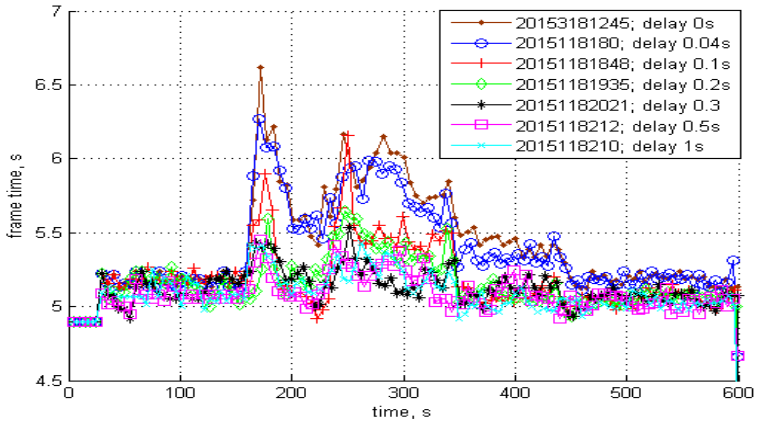
Figure 8 shows the track completeness, track occupancy, and frame times for the 52 target scenario with various bit error rate threshold settings. The results show that as bit error rate increases (i.e. BER threshold decreases), track completeness, occupancy and frame time decreases.



(a)

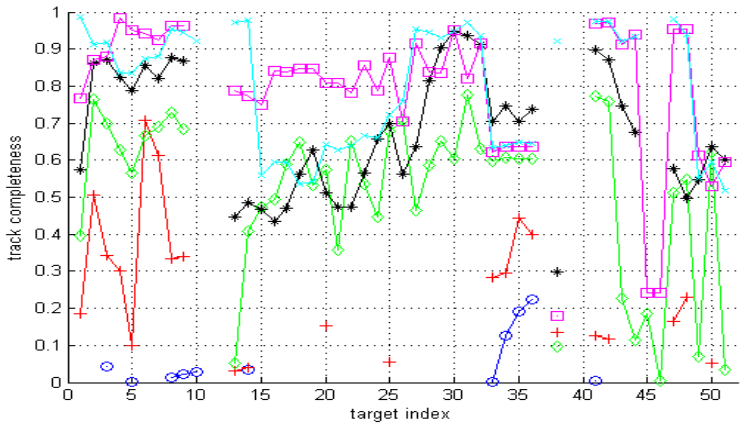


(b)

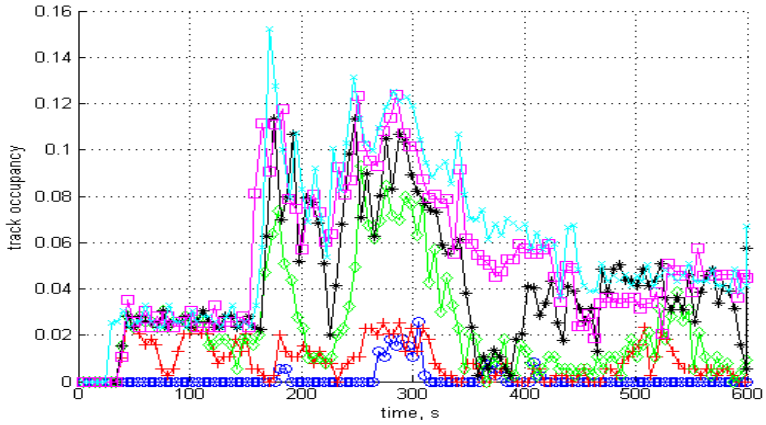


(c)

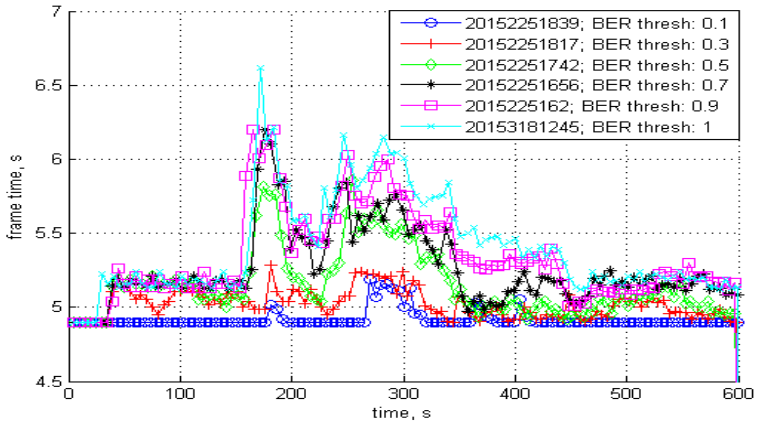
Figure 7: *Communications delay experiments, 52 targets. (a) Track completeness. (b) Track occupancy. (c) Frame time.*



(a)



(b)



(c)

Figure 8: *Bit error rate experiments, 52 targets. (a) Track completeness. (b) Track occupancy. (c) Frame time.*

4 Miscellaneous functionality

4.1 Communication channel GUI

The previous work to implement communications channel functionality [see Yue, 2014] was upgraded to allow the user to input parameters with the GUI interface.

Figure 9 shows the new GUI interface.

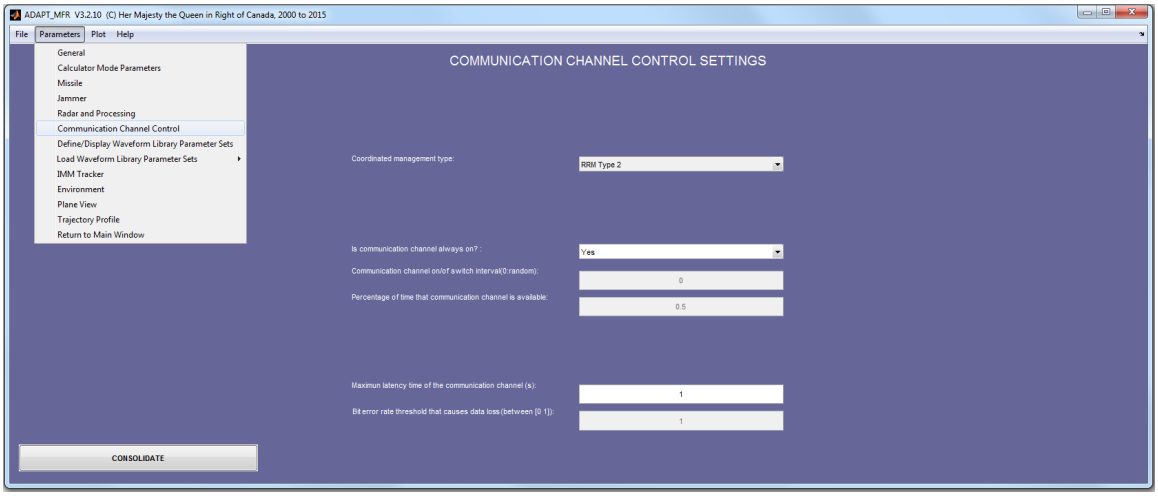


Figure 9: *Communications channel GUI*

The user input parameters are [described in detail in Yue, 2014]:

- coordinated management type (independent, RRM type 1, and RRM type 2;
- communication channel always on (yes or no);
- communication channel on/off switch interval (# or 0 = random);
- communication channel availability (percentage of time);
- communication channel latency (in seconds); and
- bit error rate threshold (placeholder; currently not used).

Files affected:

.\GUI\Adapt_MFR.m - lines 111:119
.\GUI\cbConsolidate.m - lines 419:434
.\GUI\editUiControl.m - lines 92:117

Last Modification Date:
Dec 2014

4.2 Adapt_MFR batch capability

The software was modified to allow for multiple (batch) runs without user interaction. A batch script is used in which Adapt_MFR is called multiple times with several input parameters. Each run generates several output files which have time and date identifiers in the filename.

The batch script 7 input parameters for Adapt_MFR are:

- scenario_file_name;
- staticrandflag (0 = random seed or 1 = seed 5258);
- adaptive_time_balancing (0 or 1);
- coordinated_management_type (1 = RRM type 1, 2 = RRM type 2, 3 = independent);
- non_adaptive_track_occupancy_percent (0.00 : 1.00);
- max_com_delay_seconds (0 : 1); and
- BER_thresh (0 : 1).

Example function calls:

- adapt_mfr(scenario_file_name,staticrandflag,adaptive_time_balancing,coordinated_management_type, non_adaptive_track_occupancy_percent,max_com_delay_seconds,BER_thresh);
- adapt_mfr('setup_52tgts_new_waveform_8pulse_az120_2014c.mfr',1,1,2,20,0.04,0.9);

Files affected:

.\Main\adaptmfr_run.m - lines 115:147 & 173:194
.\GUI\adapt_mfr.m - lines 323:333

Last Modification Date:
Jan 2015

5 Bug fixes

5.1 Random number seed generation

Description:
Some tests were run with different random number seeds but the results did not vary. After investigation it was discovered that the method used to generate the random numbers was not working properly. MATLAB has implemented a new method for generating random numbers in the newer version and the code was adapted to use the new method. The changes were tested and verified.

Files affected:
.\Main\adaptmfr_run.m - lines 337:348

Last Last Modification Date:
Jan 2015

5.2 Variable not cleared between runs

Description:
At the end of a simulation the (trackers) variable was not cleared properly. If another simulation was run using the same session of MATLAB and Adapt_MFR this created errors. The code was modified to clear the (trackers) variable properly.

Files affected:
.\IMM_Tracker\IMM_Tracker.m - lines 891:894

Last Modification Date:
Oct 2014

5.3 Matrix copy error (size mismatch)

Description:
The (target_trackers) structure in the (communication_channel_control) function is a temporary placeholder for observations of interest. A problem occurred when copying new observations (where some of the observation structure values had not been filled yet) into the existing target_trackers structure. The code was modified to copy structure elements individually rather then as a whole structure to resolve the issue. Code was also added to clear out empty structure elements.

Files affected:
.\Main\communication_channel_control.m - lines 77:104 & 133:134

Last Modification Date:
Nov 2014

5.4 Empty structure

Description:
Addition of new functionality and the associated tests resulted in situations where certain tracking structures could be empty (which never were previously) at the end of the simulation. Code changes were required to handle the empty tracking structures.

Files affected:
.\GUI\cbAnalysis.m - lines 153 & 299:303

Last Modification Date:
Dec 2014

5.5 Saving Adapt_MFR version number

Description:
The MATLAB *(*version) function was previously improperly used as a variable to record the Adapt_MFR version number (to tag and identify results files). The variable was renamed *(*amfr_version).

Files affected:
.\Main\adapt_mfr.m - lines 18 & 33
.\Main\adaptmfr_run.m - lines 155, 2976:2978, 3144:3157, 3176:3178 & 3190

Last Modification Date:
Feb 2015

6 Conclusion

This report summarized the work done under task 6 of contract W7714-125424/001/SV. DRDC Ottawa has contracted C-CORE for software support services relating to tracking and radar resource scheduling using the Adaptive Multi-Function Radar simulator (Adapt_MFR).

Some simulations were run to validate a previous version of the software (Adapt_MFR v3.2.5 with bug fixes and important updates) for a single radar. Results were as expected.

The main goal of this this task was to implement a model for non-ideal communication channels in Adapt_MFR which included error-free communications with data latency and partial reception of data based on data bit error rate. Software modifications were made, and the results generated using different scenarios were analyzed and compared to validate functionality. The experimental results show that as communication channel time delay increases, track completeness, occupancy and frame time decreases. Results also show that as bit error rate increases, track completeness, occupancy and frame time decreases.

7 Recommendations

It is recommended that some of the hard coded global variables, especially ones frequently modified by the user, be added to the GUI to improve the efficiency and accuracy of the simulation run.

Currently, frame time includes the time added by confirmation beams. When tracking occupancy increases (and, consequently, more confirmations occur) the frame time also increases. The expected behavior is that frame time would decrease with an increase in track occupancy. It is recommended that a modification be made to the metrics scripts to separate out confirmation beam time to resolve the issue.

In the current version of Adapt_MFR, the track update intervals for each track are updated during each simulation loop and can therefore change before the track is updated. Potentially this can result in shorter or longer update intervals than were initially commanded. It is possible to lock the update interval once initially set and unlock the interval once the track has been updated with small modifications to the software. Some experiments were executed and the results show little effect on track completeness, occupancy and frame times with this modification. This modification should be included in the next software revision.

The communication channel bit errors are currently randomly generated and the actual track observation values are not modified with bit errors. This should be added in future work to represent true communication bit error simulations.

8 References

1. Yue, B., Modeling Communication Channel Availability for Networked Radars; Adapt MFR V3.2.9 software release notes, DRDC Contract Report, DRDC-RDDC-2015-C030, Ottawa, ON, Canada: C-CORE, June 2014.

9 List of symbols/abbreviations/acronyms/initialisms

Adapt_MFR Adaptive Mulitfunction Radar
DRDC Defence Research & Development Canada
IMM-NNJPDA Interactive Multiple Model Nearest Neighbour Joint Probabilistic Data Association
MFR Multi-Function Radar
RRM Radar Resource Management