Cutoffs for Broadcast Protocols: Experimental and Theoretical Results

This repository contains the artifacts for the paper "Cutoffs for Broadcast Protocols: Experimental and Theoretical Results". It contains :

- the binary of the program used to generate and analyze random broadcast protocols. See release assets `random-broadcast`.
- a Docker image with containing the compiled binary with all dependencies installed. See packages.
- the generated data sets that the figures and analysis in the paper are based on. See release assets `random-broadcast`.

More details on the algorithm and broadcast protocols can be found in the paper, the rest of this file will explain the input & output file format as well as how to use our program.

Experiment Data

We include the data generated for the experiments in the paper as `zip` files in the release artifacts. They include the generated protocols as `.broadcast` files, as well as `experiment` files. The experiment files contain the cutoff result of the reachability algorithm as well as the execution time.

A more detailed description of the file formats can be found in the section File Formats.

> **Disclaimer**: Generating the data took several days of compute time on multiple compute nodes. The produced files are very large and checking any set of the files will take significant compute time.

Using the Broadcast Protocol Tool

> **Disclaimer**: Both the binary and container image are only compiled for the Linux amd64 architecture as the authors did not have access to an ARM based machine for testing compatibility with other architectures.

In general, the program distinguishes two modes of operation:

- **Random Generation**: This mode generates a fixed number of random examples and checks reachability on those examples. For more details see.

- **File Checking**: This mode assumes the presence of existing broadcast protocol files and will read all of them from the given directory. For more details see.

The modes are selected by setting the according CLI parameters.

CLI Parameters

The following options are supported :

```
Usage: random-broadcast [options]
Allowed options:
  -h [ --help ]                    produce help message
  --from-files arg                 check processes from existing files
  -p [ --processes ] arg (=-1)     number of process to generate & check
  -s [ --states ] arg (=-1)        number of states for each process
  -a [ --actions ] arg (=-1)       number of actions for each process
  -f [ --filename ] arg            base name for produced broadcast
protocol
                                   files
  -d [ --direct-to-last ] arg (=0) optional: allows/disallows direct
transition
                                   to last state
  --timeout-min arg (=60)          optional: configure the timeout for a
                                   reachability query in min
  --buffer arg (=10000)            optional: set the buffer size of the
                                   processing queue
  --threads arg (=-1)              optional: number of threads to be used
for
                                   reachability checking, otherwise using
all
                                   available threads
  --experiment-off                 optional: disables experiment mode
  --debug                          optional: enables debug mode
```

Random Generation

This program mode can be used to generate a fixed number of protocols (set via the `-p/--processes`) option, with a fixed number of states (set via the `-s/--states` option) and actions (set via the `-a/--actions` option).

Additionally, it requires providing a value for the `-f/--filename` flag, which specifies a prefix that will be used for naming all produced output files.

The program will then generate the following files:

- Automaton Files: They will be named according to the name supplied via the `--filename` flag, appended with the number of the automaton. Their file ending is `.broadcast`.
- `experiment_<states>x<actions>_<supplied_filename>.txt`: Stores the results of the reachability checks. The creation of this file can be disabled by setting the `--experiment-off` flag.
- (Optional) `check_<states>x<actions>_<supplied_filename>.txt`: Stores the logs of the program when `--debug` is set.

Example:

```
./random-broadcast -p 5 -a 2 -s 3 -f rand-at
```

Executing the program with these parameters will create 5 random processes with 2 actions and 3 states and will store them in files with the prefix `rand-at`.

Additional Options

By default, the program will not allow a sending action to the last state. This is a sufficient condition to exclude broadcast protocols with cutoff of 1. (Mode details can be found in the paper). However, you can allow the generation of such examples by setting the `-d/--direct-to-last` to `true`.

File Checking

In this mode the program reads all files ending with `.broadcast` in the directory specified by the path supplied to the `--from-files` flag.

It will then check reachability on all supplied protocols and produce the following file(s):

- `experiment_<dir-name>_<supplied_filename>.txt`: Stores the results of the reachability checks. The creation of this file can be disabled by setting the `--experiment-off` flag.
- (Optional) `check_<dir-name>_<supplied_filename>.txt`: Stores the logs of the program when `--debug` is set.

Example:

```
./random-broadcast --from-files ./<file_dir>/
```

Executing the program with this parameter will result in the program checking all `.broadcast` files in the directory `./<file_dir>/`.

Additional Parameters

The following parameters can be set in both modes, all of them are optional:

- `--timeout-min` : Allows to set a timeout in min for each reachability computation. The default is $60min$.
- `--buffer`: Allows to set the buffer size, i.e. how many examples are kept concurrently in memory for the worker threads. Default is 1000.
- `--threads`: Configure how many threads should be used for checking examples concurrently. By default the program will try to read the amount of threads available on your system and attempt to use all of them.
- `--debug`: Enable debug messages and store logs in `check` file.

Using the included Executable

The executable can be found as part of the release artifacts, named `random-broadcast`. It is compiled for Linux systems.

Prerequisite

In order to use the program locally, the following packages will be necessary:

- the spdlog library

- and the boost libraries

`spdlog` is used for logging and `boost` is used to generate the CLI interface.

On a Debian-based systems that can be done using:

```
# Install the libraries
sudo apt-get install libspdlog-dev libboost-all-dev
```

Using the Docker Image

Instead of building the included binary you can instead use the docker image. The program can be executed by simply using:

```
export IMG=ghcr.io/pleich/cutoffs-for-broadcast-protocols:latest
docker run ${IMG} <cli-args>
```

In this case, `ghcr.io/pleich/cutoffs-for-broadcast-protocols:latest` is the name of the docker image and `<cli-args>` are the arguments you wish to pass to the program (see).

Running the image in this fashion will, however, not store the produced files as the container storage is ephemeral. If storing the produced output is desired, this can be achieved by mounting a local directory to the container, for example, by using:

```
docker run \
  --entrypoint /storage.sh \
  -v <dir-to-store-files>:/storage \
  ${IMG} \
  <cli-args>
```

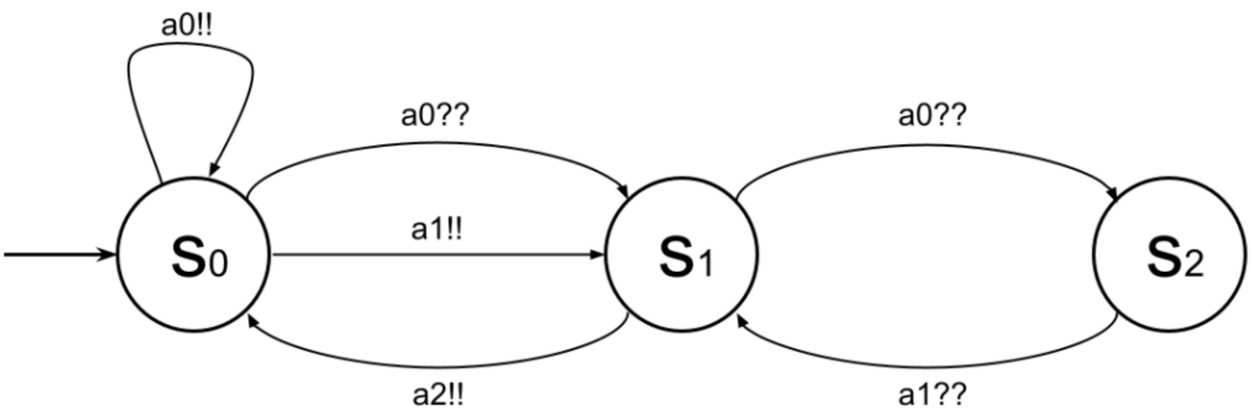
Notice that this command uses a shell script as its entrypoint. This script will compress all files into a `.zip` archive, which is very useful when producing many processes.

The same method can be used to check existing protocol files, however, the regular entrypoint can be used in that case.

File Formats

`.broadcast`

When the program is run in the `Random Generation` mode the application creates a separate `.broadcast` file for each protocol. Each protocol is given by a protocol matrix $P$ of strings, where $P [i, j]$ shows what transitions go from state $s_i$ to state $s_j$ . If no transitions go from $s_i$ to $s_j$ then $P [i, j] = e$. As we are dealing with only broadcast transitions (in particular, no rendezvous transitions exist), for simplification purposes the send and receive transitions are given by $a!$ and $a?$, respectively, instead of $a!!$ and $a??$. For example, consider the protocol with 3 states and 3 actions in the following figure:



The protocol matrix of the protocol above looks like:

$$ \begin{pmatrix} a0!a1?a2? & a1!a0? & e \ a2! & a1?a2? & a0? \ e & a1? & a0?a2? \end{pmatrix} $$

Experiment Results

The produced `experiment_<..>` files will contain entries in a human-readable format:

All entries are of the form:

```
Protocol <file-name> needs <n> processes. Check time: <t>ms Termination
reason: <reason>
```

Where :

- `<file-name>`: is the name of the file where the protocol matrix is stored.
- `<n>`: is the cutoff of the protocol. The number is negative if the final state is not reachable.
- `<t>`: is the time it took to execute the reachability check for the protocol.
- `<reason>`: represents the state with which the reachability check terminated. This should be `reachable`, `unreachable` or `timeout`. An entry with a termination reason `ERR` can occur if the input file format is invalid.

Example:

```
Protocol at_0.broadcast needs 2 processes. Check time: 0ms Termination
reason: reachable
Protocol at_1.broadcast needs 2 processes. Check time: 0ms Termination
reason: reachable
Protocol at_2.broadcast needs 2 processes. Check time: 0ms Termination
reason: reachable
Protocol at_3.broadcast needs -1 processes. Check time: 0ms Termination
reason: unreachable
```

```
Protocol at_4.broadcast needs 2 processes. Check time: 0ms Termination
reason: reachable
```

> *Disclaimer*: The files produced for the results in the paper contain begin each entry with `Automaton` instead of `Protocol`. Additionally, the check time in case of a timeout will report as `30`, an artifact of an incautious type conversion that has been fixed in this version.