Chapter 1

Evaluation

1.1 Reference Implementation

A reference implementation of **??** is available on GitHub[1]. Actors are implemented using the Akka toolkit[2], which offers high-performance and large-scale actor systems. Experimental results indicate that the reference implementation can reliably handle contact networks with 1 million individuals and 10 million contacts, which makes it ideal for small-scale experiments. In addition to using the Akka toolkit, several other optimizations are implemented:

- To reduce the size of event logs and result files, individual actor identifiers follow zero-based numbering and event records are serialized using the Ion format[3] with shortened field names.

[1] `https://github.com/cwru-xlab/sharetrace-akka`
[2] `https://doc.akka.io/docs/akka/2.8.5/typed/index.html`
[3] `https://amazon-ion.github.io/ion-docs`

- To reduce memory usage, FastUtil[4] data structures are used, including a specialized integer-based JGraphT[5] graph implementation (Michail et al., 2020). Also, singletons (Gamma et al., 1995), primitive data types, and reference equality are preferred where feasible and do not impact readability.

- To reduce runtime and increase throughput, logging is performed asynchronously with Logback[6] and the LMAX Disruptor[7].

Figure 1.1 shows the dependencies among the application components.

`Main` → `Runner` → `RiskPropagation` → `Monitor` → `User` → `Contact`

Figure 1.1: Arrow diagram of the reference implementation.

`Main` is the entry point into the application. It is responsible for parsing `Context`, `Parameters`, and `Runner` from configuration and invoking `Runner` with `Context` and `Parameters` inputs. `Context` makes application-wide information accessible, such as the system time and data time[8], a pseudorandom number generator, `Runner` configuration, and logging. `Parameters`, as the name suggests, is a collection of parameters that modify actor behavior, such as the transmission rate and send coefficient.

[4] `https://fastutil.di.unimi.it`
[5] `https://jgrapht.org`
[6] `https://logback.qos.ch/index.html`
[7] `https://lmax-exchange.github.io/disruptor`
[8] The system time is always the current time and is included in each logged event record. The data time is configurable to either be the system time or fixed at the reference time. The latter is useful for avoiding the expiration of risk scores and contacts across executions of risk propagation.

An implementation of the `Runner` interface specifies how `RiskPropagation` is created and invoked—usually through some combination of statically defined behavior and runtime configuration.

`RiskPropagation` logs the execution properties (i.e., context, parameters, and data generation properties), creates an Akka `ActorSystem` that creates a `Monitor` actor, sends it a `RunMessage`, and waits until it terminates. `RiskPropagation` is equivalent to the driver in the driver-monitor-worker framework that was used in prior implementations (see **??**).

The `Monitor` creates `User` actors, sends each `User` `ContactMessage`s, and sends each `User` a `RiskScoreMessage`. By sending a `User` its contacts before its risk score, Akka guarantees[9] that each `User` receives its contacts before receiving any risk scores. The `Monitor` logs `LifecycleEvent`s that demarcate the start and end each activity. These logged events allow the runtime of these activities to be determined. Once the `Monitor` has finished sending risk scores, it waits up to `idleTimeout` time before terminating. Each time the `Monitor` receives a `UserUpdatedMessage`, it resets the timer.

`User` and `Contact` correspond to their descriptions in **??**. Similar to `Monitor`, each `User` emits `UserEvent`s in the event log for analysis.

An experiment typically composed of multiple configuration files in order to vary an aspect of the

An execution is defined by one or more invocations of risk propagation that are associated with the same configuration file.

Multiple invocations may be needed to compute statistics when the data

[9] `https://doc.akka.io/docs/akka/current/general/jmm.html#actors-and-the-java-memory-model`

generation process is stochastic.

An execution may involve multiple invocations of risk propagation in order to collect multiple results from the same configuration. This is particularly relevant when the data generation process involves

Analysis sequence:

1. Load execution properties.
2. Stream the event records, processing each record by one or more `EventHandler`s.
3. Put the results from each `EventHandler` in a `Results` instance.
4. Transform the `Results` instance it into a tabular dataset.
5. Analyze the dataset.

1.1.1 Experimental Design

The following research questions were the focus of evaluation:

1. How do the send coefficient and tolerance affect the accuracy and efficiency of risk propagation?
2. What is the runtime performance of risk propagation?

Barabasi–Albert graphs (Barabàsi and Albert, 1999) are parametrized by the order n, the initial order n_0, and the size increase m_0 upon each incremental increase to the order. The latter two parameters are determined by solving

Parameter	Default value
Seed	12 345
Transmission rate	0.8
Send coefficient	1.0
Time buffer	2 days
Risk score expiry	14 days
Contact expiry	14 days
Tolerance	0
Flush timeout	3 seconds
Idle timeout	1 minute

(1.1), where $\operatorname{frac}(x)$ is the fractional part of a real number x.

$$\begin{aligned} \underset{n_0,\, m_0}{\arg\min} \quad & \operatorname{frac}(m_0) \\ \text{subject to} \quad & n_0 \in [1\,..\,n-1], \\ & m_0 \in [1\,..\,n_0], \\ & m_0 = \frac{2m - n_0(n_0-1)}{2(n-n_0)} \end{aligned} \tag{1.1}$$

Erdös–Rényi $G_{n,m}$ random graphs (Erdös and Rényi, 1959) are parametrized by the order n and the size m. Random regular graphs (Kim and Vu, 2003) are parametrized by the order n and, using the degree sum formula, the degree $d = \lfloor \frac{2m}{n} \rfloor$. Lastly, Watts–Strogatz graphs (Watts and Strogatz, 1998) are parametrized by the order n, the rewiring probability p and the number of nearest neighbors $k = d + (d \bmod 2)$, which must be even.

The default Akka configuration[10].

- Fixed clock time

[10] `https://doc.akka.io/docs/akka/current/general/configuration-reference.html`

- Monitor actor:
  - PinnedDispatcher
  - Thread pool executor
  - No core timeout
- User actors:
  - Dispatcher
  - Thread pool executor
  - 100 throughput
  - Max pool size: 2 147 483 647 (max Java integer value)
- 5 contact networks with distinct risk scores and contact times
- Sampling procedure to generate dataset values: Given a probability density function f_X and cumulative distribution function F_X of a random variable X, sample a value $x \sim f_X$ and evaluate $F_X(x)$.

Parmeter experiments:

- $n = 10^4$, $m = 5 \cdot 10^4$
- Distributions: uniform, standard normal
- Send coefficients: 0.8–2.0, in increments of 0.1
- Tolerance: 0.001–0.01, in increments of 0.001
- All 9 distribution combinations: uniform, standard normal

- 5 contact networks with distinct risk scores and contact times

Runtime baseline experiment:

- $n = 10^4$, $m = 10^5$
- All 9 distribution combinations: uniform, standard normal
- 1 burn-in + 5 contact networks with distinct risk scores and contact times
- Log lifecycle events and last event for message-passing runtime

Runtime experiment:

- Cross product of $n \in \{ 10^5 x \mid x \in [1, 10] \}$ and $m \in \{ 10^6 x \mid x \in [1, 10] \}$
- Uniform distribution for all 3 data types
- 1 burn-in + 5 contact networks with distinct risk scores and contact times
- Log lifecycle events and last event for message-passing runtime

1.1.2 Results

Bibliography

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[6] Duncan J Watts and Steven H Strogatz. “Collective dynamics of ‘small-world’ networks”. In: *Nature* 393.6684 (1998), pp. 440–442 (cit. on p. 5).