The Scalable Simulation Framework and SSF network models

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Overview

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SSFnet at a glance

SSFnet project has two main components:

- research on and development of scalable modeling and simulation tools and
- using these tools - research on the dynamic behavior of very large networks

Software research:

- focus on scalability: modeling scalability, performance scalability

Network research:

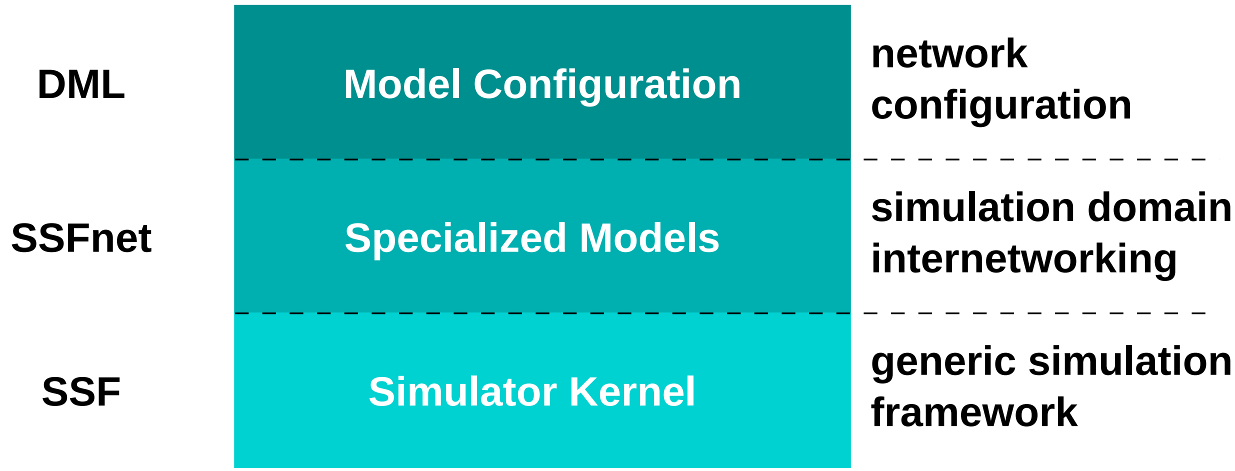
- help address a number of modeling and simulation challenges

How to build scalable simulations

- generic simulation framework, which provides mechanisms for simulation of arbitrary applications
- specialized ”models” provide a mapping from the simulated world to the simulator world
- a model imitates the behaviour of a real component by using the mechanisms provided by the simulator
- models may need specific configuration, when instantiated

SSFnet building blocks

The SSFnet framework consists of several components:



Scalable Simulation Framework (SSF)

Provides a single, unified API to the simulator kernel:

- five base class interfaces `Event`, `Entity`, `inChannel`, `outChannel` and `process`.
- Java and C++ bindings
- not limited to simulate communication networks
- simulation domain determined by specific models atop of SSF
- built-in multiprocessor support

Entity

- base class for **all** simulation components
- **Examples**: hosts, routers, links, TCP sessions, etc.
- container mechanism for defining alignment relations among a model's pieces
- coaligned entities presumably interact through event exchange on channels
- underlying simulator takes this into account, when mapping entities to processors
- Methods: `now()`, `startAll()`, `pauseAll()`, `resumeAll()`, `joinAll()`, `alignto()`, `alignment()`, `coalignedEntities()`, `init()`, `processes()`, `inChannels()` and `outChannels()`

Event

- base class for the quantum of information flowing over channels
- **Examples**: protocol packets and timers
- Methods: `save()`, `release()` and `aliased()`

process

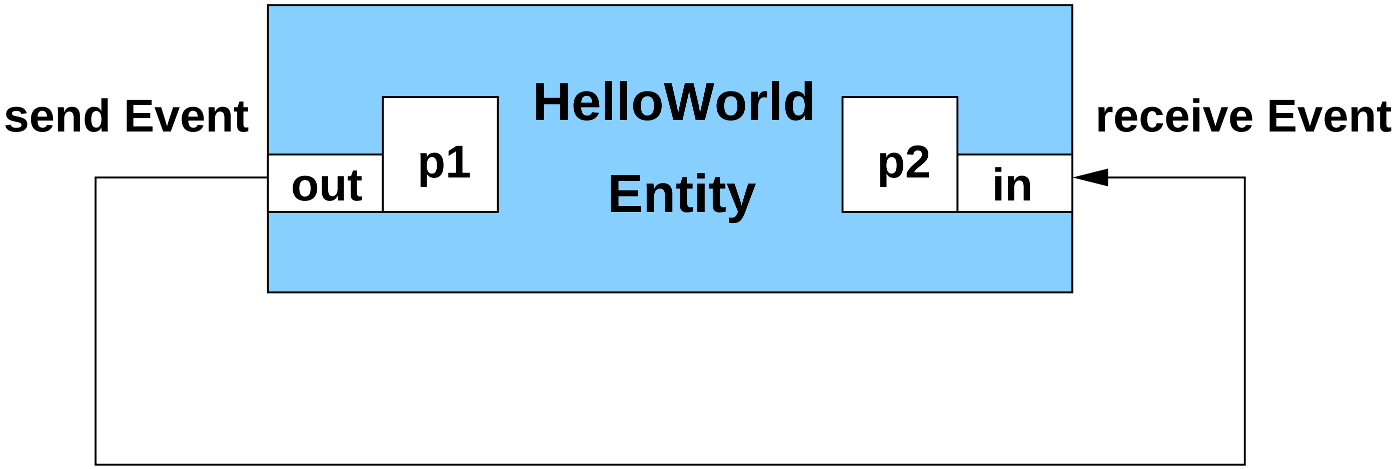
- base class for describing an entity's behavior
- **Examples**: run-time behaviour of protocols, etc.
- each instance of a process is associated with a specific entity
- may wait for input arriving on inChannels or wait for time to elapse
- may also wait on channels of entities coaligned with its owner
- Methods: `owner()`, `action()`, `init()`, `waitOn()`, `waitForever()`, `waitFor()`, `waitOnFor()` and `isSimple()`

inChannel, outChannel

- communication endpoints for event exchange
- **Examples**: protocol interaction, etc.
- each instance belongs to a specific entity
- multicast in- (many to one) and outChannels (one to many) and bus-style channel mappings (many to many)
- outChannels have a transmission delay associated with them
- inChannel Methods: `owner()`, `activeEvents()` and `mappedTo()`
- outChannel Methods: `owner()`, `mappedTo()`, `write()`, `mapTo()` and `unmap()`

Example: HelloWorld

This is a simple example to demonstrate the execution of a SSF simulation.



Example: HelloWorld (cont.)

```
import com.renesys.raceway.SSF.*;

public class HelloWorld extends Entity {

    public long DELAY = 20;
    public int rcvd;

    public inChannel IN;
    public outChannel OUT;
```

Example: HelloWorld (cont.)

```
public HelloWorld() {
    rcvd = 0;
    IN = new inChannel( this );
    OUT = new outChannel( this, DELAY );

    OUT.mapto( IN );

    new process(this) {
            public void action() {
                OUT.write(new Event());
                waitFor( DELAY );
            }
        };
```

Example: HelloWorld (cont.)

```
        new process(this) {
                public void action() {
                    waitOn( IN );
                    rcvd++;
                }
            };
    }
```

Example: HelloWorld (cont.)

```
    public static void main(String[] argv) {
        HelloWorld hello = new HelloWorld();

        hello.startAll( 200 );
        hello.joinAll();
        System.out.println("total received events = "+hello.rcvd);
    }
}
```

SSF implementations

SSF implementations available:

- **Raceway**: High-performance commercial implementation of the Java SSF API from Renesys Corp.
- **JSSF**: Reference implementation of the Java SSF API from Cooperating Systems Corp.
- **CSSF**: Reference implementation of the C++ SSF API from Cooperating Systems Corp.
- **DaSSF**: High-performance implementation of the C++ SSF API from Dartmouth College

SSF Network Models (SSFnet)

"SSFnet provides open-source Java models of protocols (IP, TCP, UDP, BGP4, OSPF and others), network elements (hosts, routers, links, LANs) and assorted support classes for realistic multi-protocol, multi-domain internet modeling and simulation."

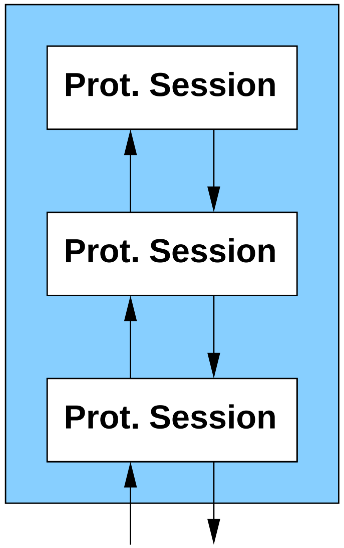
- collection of components for simulation at IP level and above
- configurable at run-time through a configuration database
- two parts: SSF.OS (modeling of the host and operating system components, such as protocols), SSF.Net (network connectivity, node and link configuration)

Available protocols and applications

- Routing:
  - SSF.OS.IP
  - SSF.OS.OSPF
  - SSF.OS.BGP4
- Transport:
  - SSF.OS.TCP
  - SSF.OS.UDP
  - SSF.OS.Socket
- Applications/workload:
  - TCP and UDP clients/servers
  - HTTP clients/servers

SSF.OS

Principal classes: `ProtocolGraph`, `ProtocolSession`, `ProtocolMessage` and `PacketEvent`



SSF.OS (cont.)

- protocol implementations must be derived from `ProtocolSession`
- each protocol graph is an entity with in- and out-channels for exchanging PacketEvents
- protocol messages represent packet headers and payload of packets specific to a protocol
- `PacketEvent` is a wrapper class, that turns a protocol message into an event, which can be sent over a channel

SSF.Net

- principal classes: `Net`, `Host`, `Router`, `NIC` and `link`
- `Net` loads the configuration and instantiates the entire model
- `Host` is derived from `ProtocolGraph` and must minimally include IP and at least one Network Interface Card (NIC)
- `Router` is a special class derived from `Host`
- `NIC` is a pseudo-protocol which maintains a pair of in- and out-channels connected to the world outside the `ProtocolGraph`
- `a` link connects a NIC to other NICs on the same link

Monitoring possibilities

- support for export of flow data in Cisco NetFlow format
- support for dumps of packet data in tcpdump format
- TCP instrumentation for dumps of internal state variables of active TCP connections

Domain Modeling Language (DML)

- DML configuration provides the configuration for specific instances of SSFnet objects
- used for configuring network models and modeling topologies
- schemas provide a mechanism for flexible syntax checking of models
- easy to introduce new schemas with new protocol models

Example for a DML configuration

```
router[
    interface[id 0 bitrate 100000000 latency 0.0001]
    interface[id 1 bitrate 100000000 latency 0.0001]
    interface[id 2 bitrate 100000000 latency 0.0001]
    interface[id 3 bitrate 100000000 latency 0.0001]
    graph[
        ProtocolSession[name ip use SSF.OS.IP]
        ProtocolSession[name ospf use SSF.OS.OSPF.sOSPF]
    ]
]
```

Example for a DML schema

```
host [
  graph %T1!:.schemas.graph   # protocol graph specification

  interface [ _extends .schemas.interface
    id %I idrange [from %I1! to %I1!]
    ip %S
  ]

  _find .schemas.route        # Static routes for this host
  _find .schemas.nhi_route
]

router [_extends .schemas.host]
```

DML syntax

- list of whitespace-separated key and value pairs
- keys are alphanumerical strings
- reserved names begin with an underscore "_"
- a value is a string or a DML expression enclosed in sqaure brackets
- value strings are arbitrary ASCII strings enclosed in double quotes
- quotes may be omitted, if the value string does not include whitespaces nor sqare brackets
- value strings may be regular expressions (special characters escaped by a backslash)

DML schema format

- a schema specifies the format of an attribute tree by specifying key names, attribute value types and the number of attribute instances
  - %S - String attribute with any number of instances
  - %I1 - Integer attribute with at least one instance
  - %F2! - Float attribute with exactly two instances
  - %S2<5 - String attribute with 2, 3, 4 or 5 instances
  - %T1:.key1.key2 - Internal attribute with at least 1 instance
  - %S<2:[1-9][0-9]*[\t]+[GMkK]B - String with at most 2 instances matching the regular expression (e.g. 125 kB)

Reserved DML attributes

- **_schema**: points to a DML tuple, which defines the schema of an attribute
- **_find**: is replaced by the DML tuple specified (has-a relation)
- **_extends**: make this attribute inherit all attributes in the specified path (is-a relation)

Attribute ordering

- the order of attributes of a different name is insignificant
- the order of attributes with the same name is significant, e.g. the order of `ProtocolSession` attributes can be used o determine the order of protocol initialization

Example:

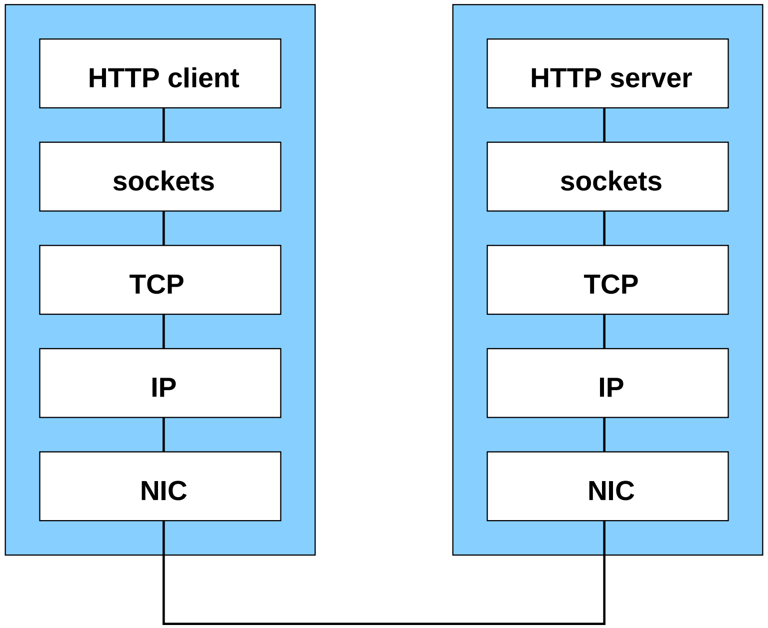
```
graph [
    ProtocolSession[name server use test.masterServer port 10]
    ProtocolSession[name socket use SSF.OS.Socket.socketMaster]
    ProtocolSession[name tcp use SSF.OS.TCP.tcpSessionMaster]
    ProtocolSession[name ip use SSF.OS.IP]
]
```

Further information

- Information about SSFnet can be obtained from:
  http://www.ssfnet.org
- Information about the Dartmouth SSF implementation:
  http://www.cs.dartmouth.edu/research/DaSSF
- BGP and OSPF implementations in SSFnet:
  http://www.cs.dartmouth.edu/∼beej/research
- These slides: *http://www.d-jacob.net/diplom*

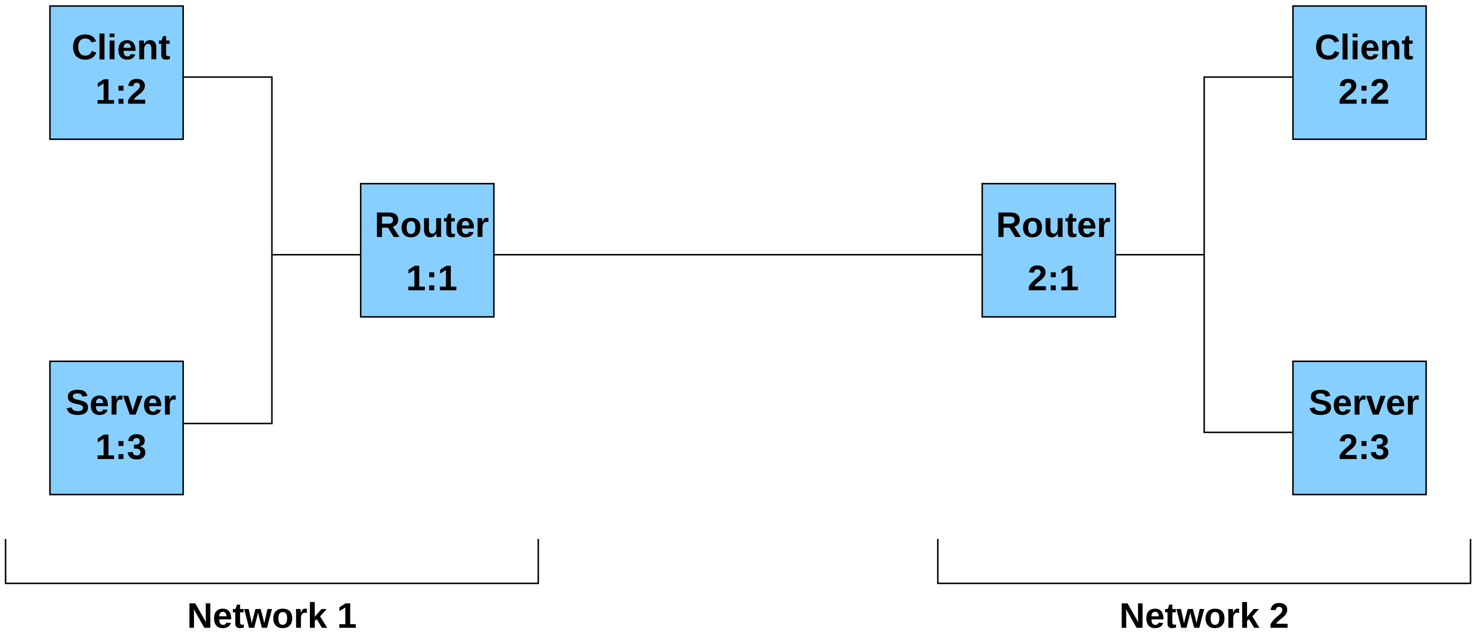
Example 1: Peer-to-peer network

Topology:



Example 2: Simple AS with routing

Topology:



Example 3: Two AS's with BGP and OSPF

Topology: