Distributed systems abstractions
(PDCS 9, CPE 6*)

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* Concurrent Programming in Erlang, by J. Armstrong, R. Virding, C. Wikström, M. Williams
Overview of programming distributed systems

- It is harder than concurrent programming!
- Yet unavoidable in today’s information-oriented society, e.g.:
  - Internet, mobile devices
  - Web services
  - Cloud computing
- Communicating processes with independent address spaces
- Limited network performance
  - Orders of magnitude difference between WAN, LAN, and intra-machine communication.
- Localized heterogeneous resources, e.g, I/O, specialized devices.
- Partial failures, e.g. hardware failures, network disconnection
- Openness: creates security, naming, composability issues.
SALSA Revisited

- **SALSA**
  - Simple Actor Language System and Architecture
  - An actor-oriented language for mobile and internet computing
  - Programming abstractions for internet-based concurrency, distribution, mobility, and coordination


- **Advantages for distributed computing**
  - Actors encapsulate state and concurrency:
    - Actors can run in different machines.
    - Actors can change location dynamically.
  - Communication is asynchronous:
    - Fits real world distributed systems.
  - Actors can fail independently.
World-Wide Computer (WWC)

- Distributed computing platform.
- Provides a run-time system for *universal actors*.
- Includes naming service implementations.
- Remote message sending protocol.
- Support for universal actor migration.
Abstractions for Worldwide Computing

- *Universal Actors*, a new abstraction provided to guarantee unique actor names across the Internet.

- *Theaters*, extended Java virtual machines to provide execution environment and network services to universal actors:
  - Access to local resources.
  - Remote message sending.
  - Migration.

- *Naming service*, to register and locate universal actors, transparently updated upon universal actor creation, migration, garbage collection.
Universal Actor Names (UAN)

- Consists of *human readable* names.
- Provides location transparency to actors.
- Name to locator mapping updated as actors migrate.
- UAN servers provide mapping between names and locators.
  - Example Universal Actor Name:
    
    `uan://wwc.cs.rpi.edu:3030/cvarela/calendar`

    - Name server address and (optional) port.
    - Unique relative actor name.
Universal Actor Locators (UAL)

- Theaters provide an execution environment for universal actors.
- Provide a layer beneath actors for message passing and migration.
- When an actor migrates, its UAN remains the same, while its UAL changes to refer to the new theater.
- Example Universal Actor Locator:

  \[\text{rmsp://wwc.cs.rpi.edu:4040}\]

  Theater’s IP address and (optional) port.
SALSA Language Support for Worldwide Computing

• SALSA provides linguistic abstractions for:

  – Universal naming (UAN & UAL).
  – Remote actor creation.
  – Location-transparent message sending.
  – Migration.
  – Coordination.

• SALSA-compiled code closely tied to WWC run-time platform.
Universal Actor Creation

• To create an actor locally

    TravelAgent a = new TravelAgent();

• To create an actor with a specified UAN and UAL:

    TravelAgent a = new TravelAgent() at (uan, ual);

• To create an actor with a specified UAN at current location:

    TravelAgent a = new TravelAgent() at (uan);
TravelAgent a = new TravelAgent();

a <- book( flight );
Remote Message Sending

- Obtain a remote actor reference by name.

```java
TravelAgent a = (TravelAgent)
    TravelAgent.getReferenceByName("uan://myhost/ta");

a <- printItinerary();
```
module dcell;

behavior Cell implements ActorService {

    Object content;

    Cell(Object initialContent) {
        content = initialContent;
    }

    Object get() {
        standardOutput <- println ("Returning: "+content);
        return content;
    }

    void set(Object newContent) {
        standardOutput <- println ("Setting: "+newContent);
        content = newContent;
    }

}
module dcell;

behavior CellTester {

    void act( String[] args ) {

        if (args.length != 2){
            standardError <- println("Usage: salsa dcell.CellTester <UAN> <UAL>"));
            return;
        }

        Cell c = new Cell(0) at (new UAN(args[0]), new UAL(args[1]));

        standardOutput <- print("Initial Value:" ) @
        c <- get() @ standardOutput <- println(token);
    }
}

C. Varela
module dcell;

behavior GetCellValue {

    void act( String[] args ) {
        if (args.length != 1){
            standardOutput <- println(
                "Usage: salsa dcell.GetCellValue <CellUAN>"");
            return;
        }

        Cell c = (Cell) Cell.getReferenceByName(args[0]);

        standardOutput <- print("Cell Value:" @
        c <- get() @
        standardOutput <- println(token);
    }
}

C. Varela
module addressbook;
import java.util.*

behavior AddressBook implements ActorService {

    Hashtable name2email;
    AddressBook() {
        name2email = new HashTable();
    }

    String getName(String email) { ... }
    String getEmail(String name) { ... }
    boolean addUser(String name, String email) { ... }

    void act(String[] args) {
        if (args.length != 0) {
            standardOutput<-println("Usage: salsa -Duan=<UAN> -Dual=<UAL> addressbook.AddressBook");
        }
    }
}
module addressbook;

behavior AddUser {
    void act( String[] args ) {
        if (args.length != 3){
            standardOutput<-println("Usage: salsa addressbook.AddUser <AddressBookUAN> <Name> <Email>");
            return;
        }
        AddressBook book = (AddressBook)
                        AddressBook.getReferenceByUAN(new UAN(args[0]));
        book<-addUser(args(1), args(2));
    }
}
module addressbook;

behavior GetEmail {
  void act(String[] args) {
    if (args.length != 2){
      standardOutput <- println("Usage: salsa addressbook.GetEmail <AddressBookUAN> <Name>");
      return;
    }
    getEmail(args(0),args(1));
  }

  void getEmail(String uan, String name){
    try{
      AddressBook book = (AddressBook) AddressBook.getReferenceByName(new UAN(uan));
      standardOutput <- println(name + "'s email: ") @
      book <- getEmail(name) @
      standardOutput <- println(token);
    } catch (MalformedUANException e){
      standardError<-println(e);
    }
  }
}
Erlang Language Support for Distributed Computing

• Erlang provides linguistic abstractions for:
  – Registered processes (actors).
  – Remote process (actor) creation.
  – Remote message sending.
  – Process (actor) groups.
  – Error detection.

• Erlang-compiled code closely tied to Erlang node run-time platform.
Erlang Nodes

• To return our own node name:

  ```
  node()
  ```

• To return a list of other known node names:

  ```
  nodes()
  ```

• To monitor a node:

  ```
  monitor_node(Node, Flag)
  ```

  If `flag` is true, monitoring starts. If false, monitoring stops. When a monitored node fails, `{nodedown, Node}` is sent to monitoring process.
Actor Creation

- To create an actor locally

\[ Agent = \text{spawn}(\text{travel, agent, []}); \]

- To create an actor in a specified remote node:

\[ Agent = \text{spawn}(\text{host, travel, agent, []}); \]

travel is the module name,
agent is the function name,
Agent is the actor name.

host is the node name.
Actor Registration

- To register an actor:

  \texttt{register(ta, Agent)}

- To return the actor identified with a registered name:

  \texttt{whereis(ta)}

- To remove the association between an atom and an actor:

  \texttt{unregister(ta)}
Message Sending

Agent = \texttt{spawn}(\texttt{travel}, \texttt{agent}, []),
\texttt{register}(\texttt{ta}, \texttt{Agent})

Agent ! \{\texttt{book}, \texttt{Flight}\}
\texttt{ta} ! \{\texttt{book}, \texttt{Flight}\}

\textbf{Message sending syntax is the same (!) with actor name (Agent) or registered name (ta).}
Remote Message Sending

- To send a message to a remote registered actor:

\{ta, host\} \! \{book, Flight\}
Reference Cell Service Example

-module(dcell).
-export([cell/1,start/1]).

cell(Content) ->
    receive
        {set, NewContent} -> cell(NewContent);
        {get, Customer}   -> Customer ! Content,
                            cell(Content)
    end.

start(Content) ->
    register(dcell, spawn(dcell, cell, [Content]))
Reference Cell Tester

-module(dcellTester).
-export([main/0]).

main() -> dcell:start(0),
            dcell!{get, self()},
            receive
              Value ->
                io:format("Initial Value:~w~n", [Value])
            end.
-module(dcellClient).
-export([getCellValue/1]).

getCellValue(Node) ->
    {dcell, Node}!{get, self()},
    receive
        Value ->
            io:format("Initial Value:~w\n", [Value])
    end.
Address Book Service

-module(addressbook).
-export([start/0,addressbook/1]).

start() ->
    register(addressbook, spawn(addressbook, addressbook, [[[]]])).

addressbook(Data) ->
    receive
        {From, {addUser, Name, Email}} ->
            From ! {addressbook, ok},
            addressbook(add(Name, Email, Data));
        {From, {getName, Email}} ->
            From ! {addressbook, getname(Email, Data)},
            addressbook(Data);
        {From, {getEmail, Name}} ->
            From ! {addressbook, getemail(Name, Data)},
            addressbook(Data)
    end.

add(Name, Email, Data) -> ... 
getName(Email, Data) -> ... 
getemail(Name, Data) -> ...
Address Book Client Example

-module(addressbook_client).
-export([getEmail/1,getName/1,addUser/2]).

addressbook_server() -> 'addressbook@127.0.0.1'.

getEmail(Name) -> call_addressbook({getEmail, Name}).
getName(Email) -> call_addressbook({getName, Email}).
addUser(Name, Email) -> call_addressbook({addUser, Name, Email}).

call_addressbook(Msg) ->
    AddressBookServer = addressbook_server(),
    monitor_node(AddressBookServer, true),
    {addressbook, AddressBookServer} ! {self(), Msg},
    receive
        {addressbook, Reply} ->
            monitor_node(AddressBookServer, false),
            Reply;
        {nodedown, AddressBookServer} ->
            no
    end.
51. How would you implement the join block linguistic abstraction considering different potential distributions of its participating actors?

52. CTM Exercise 11.11.3 (page 746). Implement the example using SALSA/WWC and Erlang.

53. PDCS Exercise 9.6.3 (page 203).

54. PDCS Exercise 9.6.9 (page 204).

55. PDCS Exercise 9.6.12 (page 204).

56. Write the same distributed programs in Erlang.