Efficient Session Type Guided Distributed Interaction

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Purdue University

Motivation

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  - Limitations
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      - Overuse can lead to poor performance
    - cannot reason about sessions

Invitation Example - The Setting

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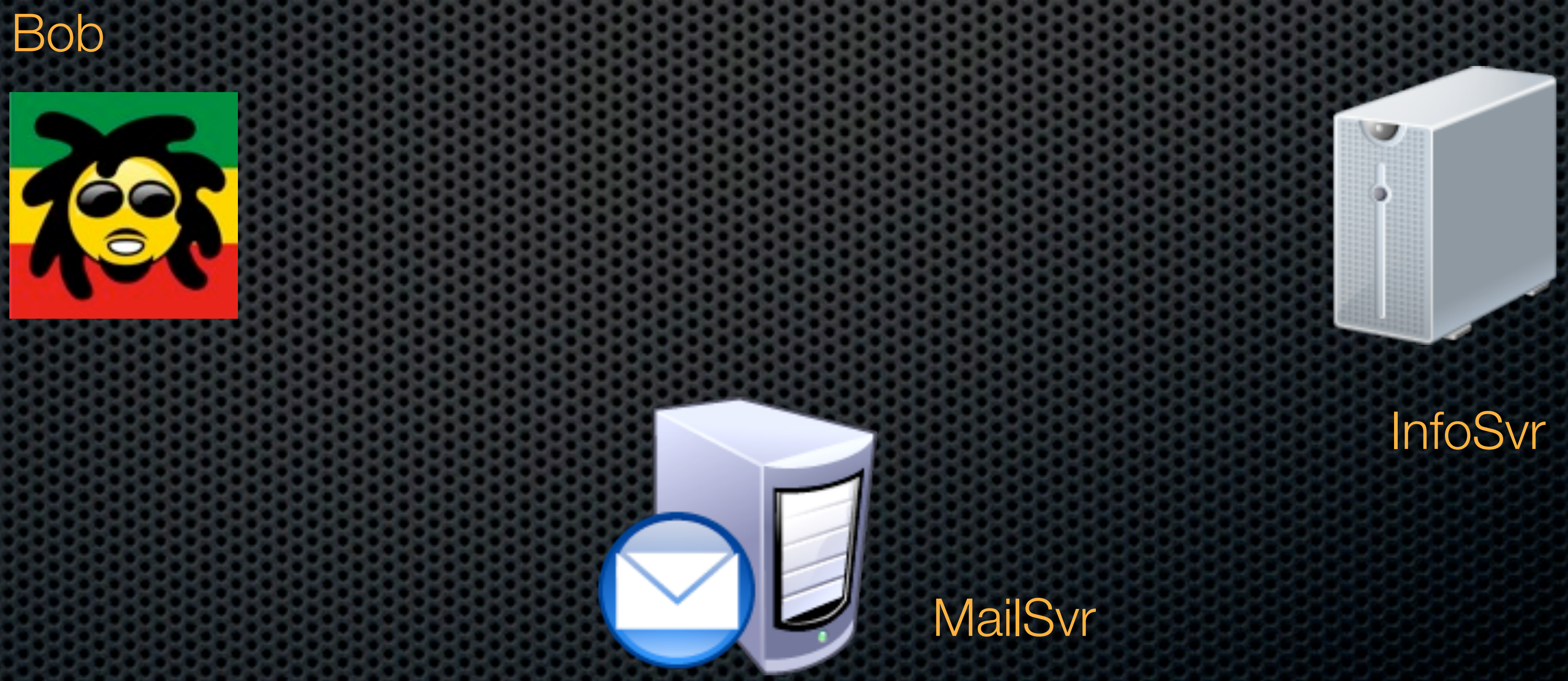
- Utilize a social networking API for accessing friends' data
- Social networking API is implemented in Java RMI
- Email invitation is sent for chosen colleagues

Invitation Example - RMI Style



Invitation Example - RMI Style

```
void invite_coworkers() {
  Event evt = me.createEvent(“party”,“June 7th, 2010);
  Employer myEmp = me.getEmployer();
  Location myLoc = me.getLocation();
  for (Member friend : me.getFriends()) {
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Bob

InfoSvr

MailSvr

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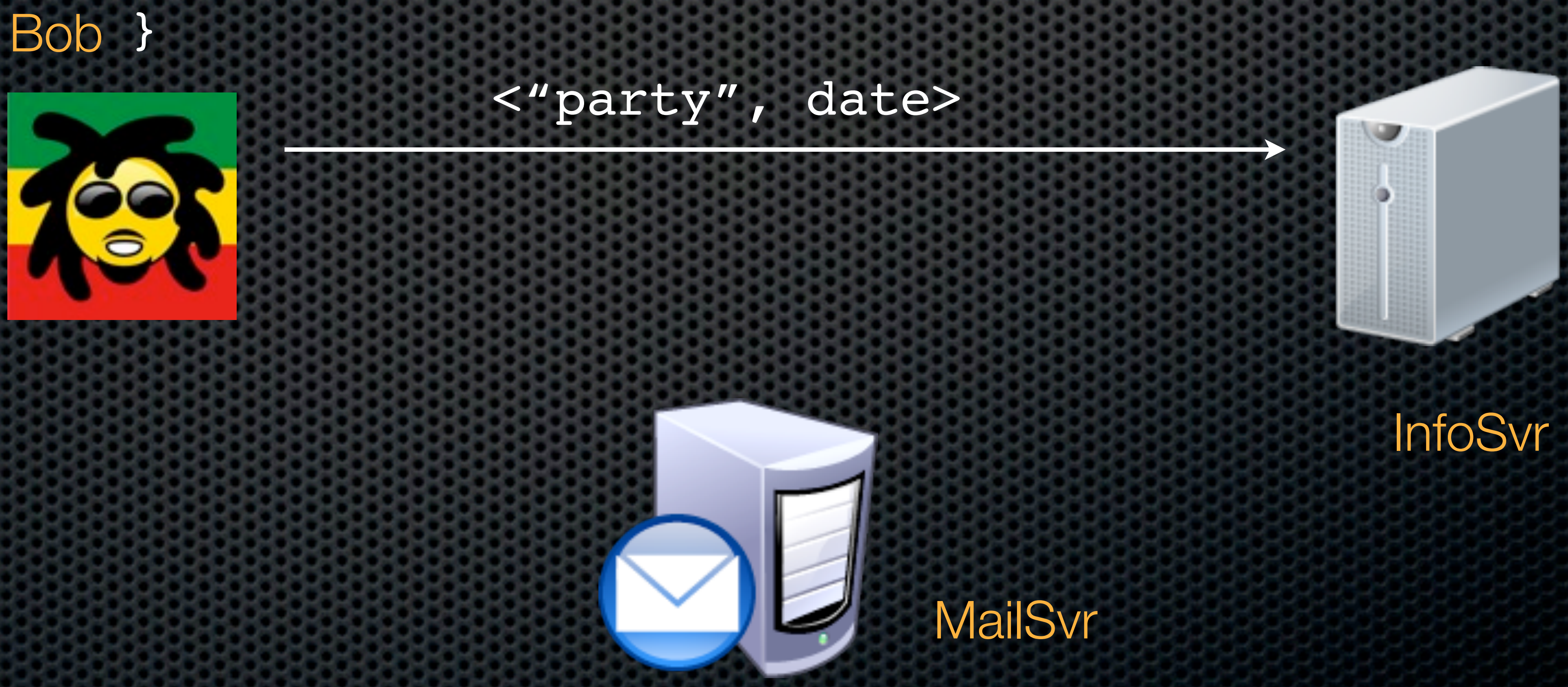

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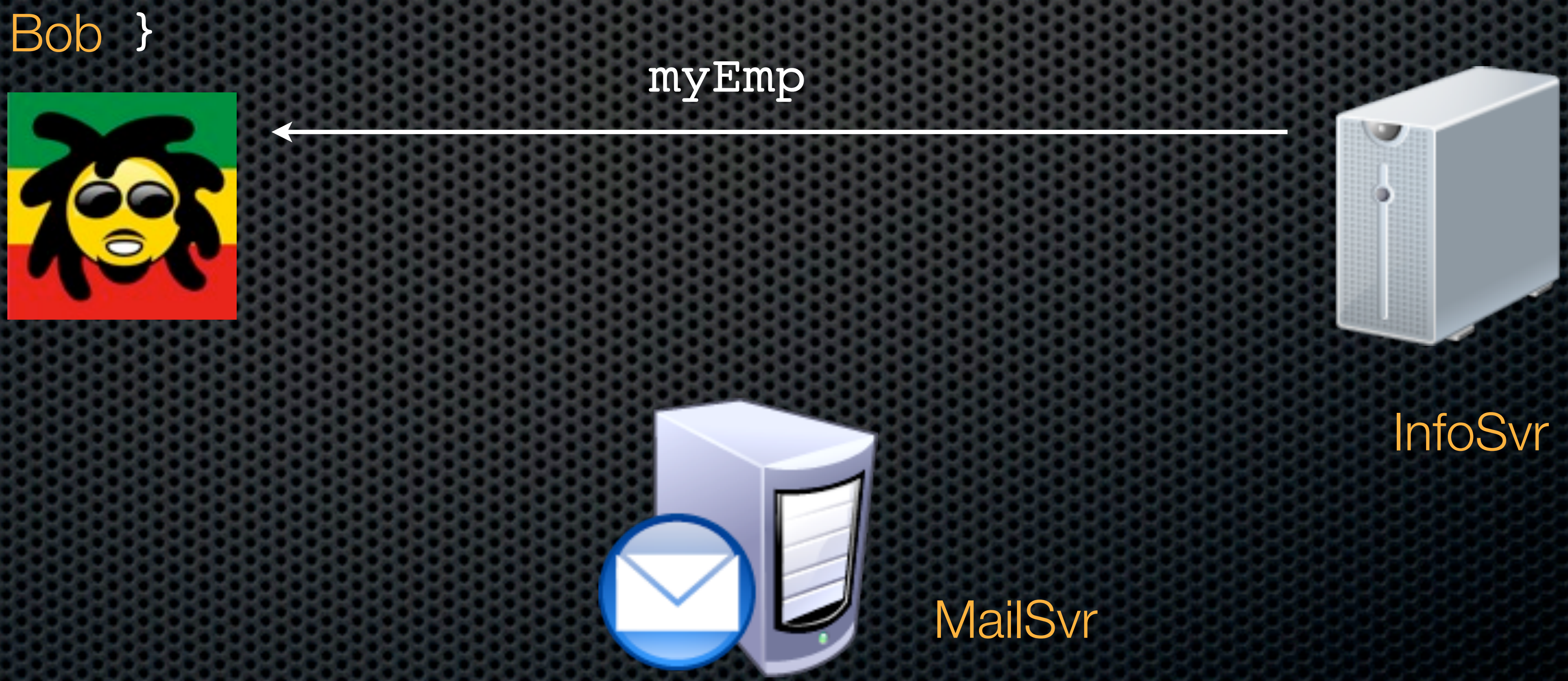

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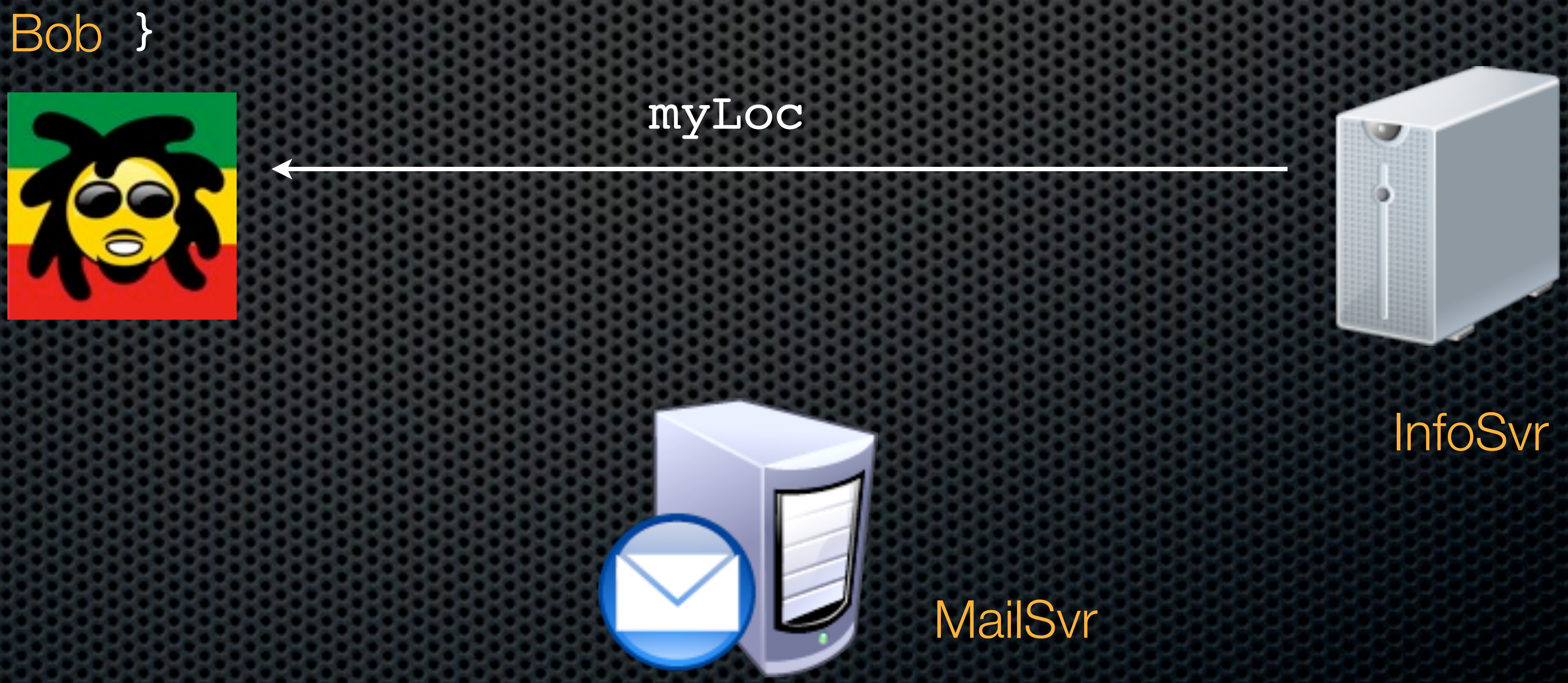

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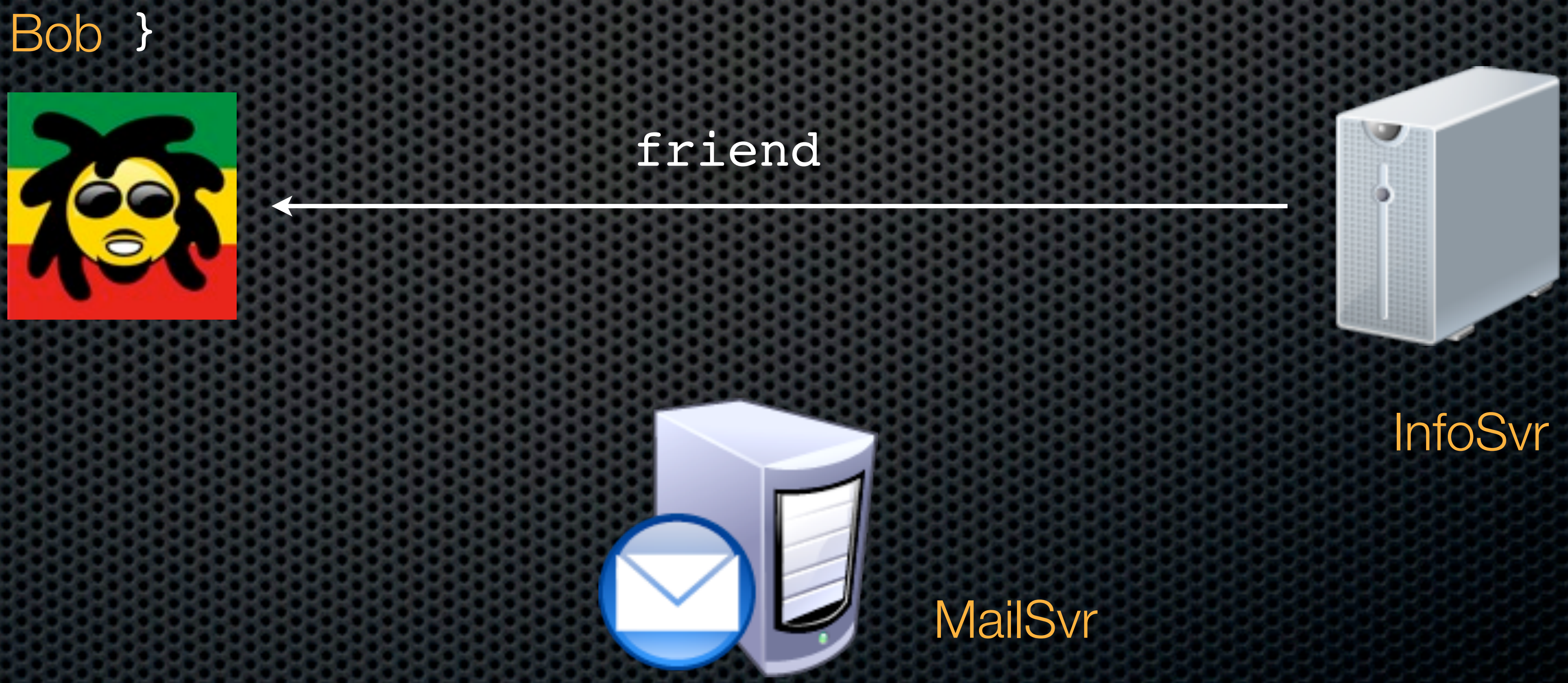

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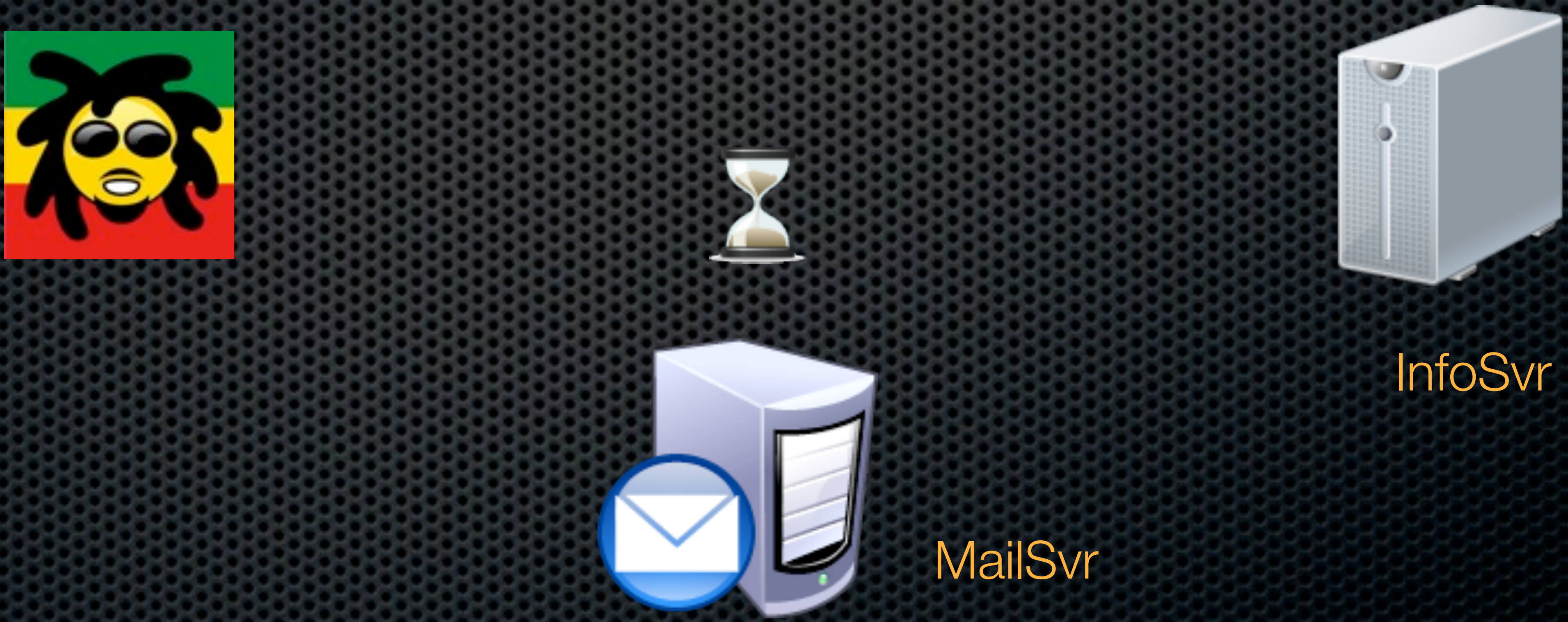

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  - Explicit control flow information through label selection and recursive types
- Multiparty Asynchronous Session Types [Honda et al. POPL '08]
- bi-party session types for Java [Hu et al. ECOOP '08]

Session Type Guided Optimization

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  - Compiler and runtime framework

Simple Example

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Bob

DeepThought

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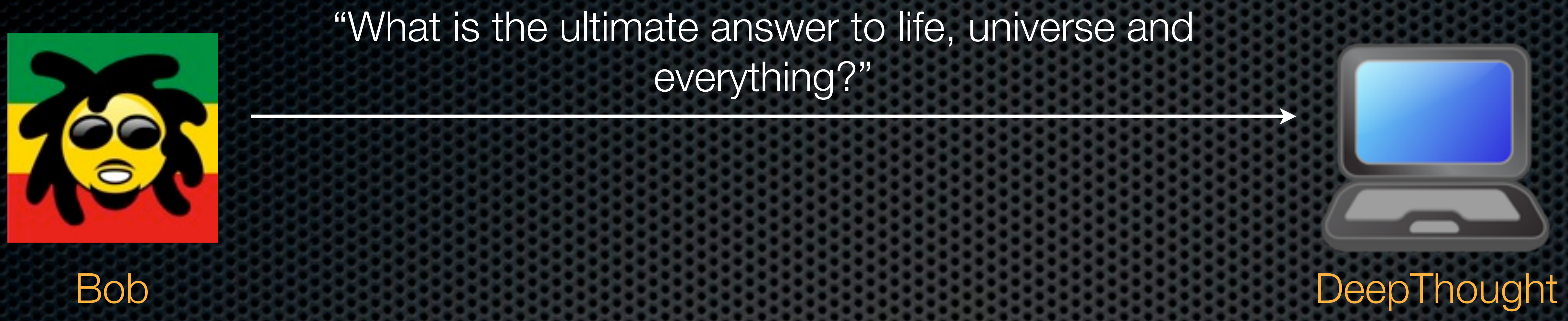

“What is the ultimate answer to life, universe and everything?”

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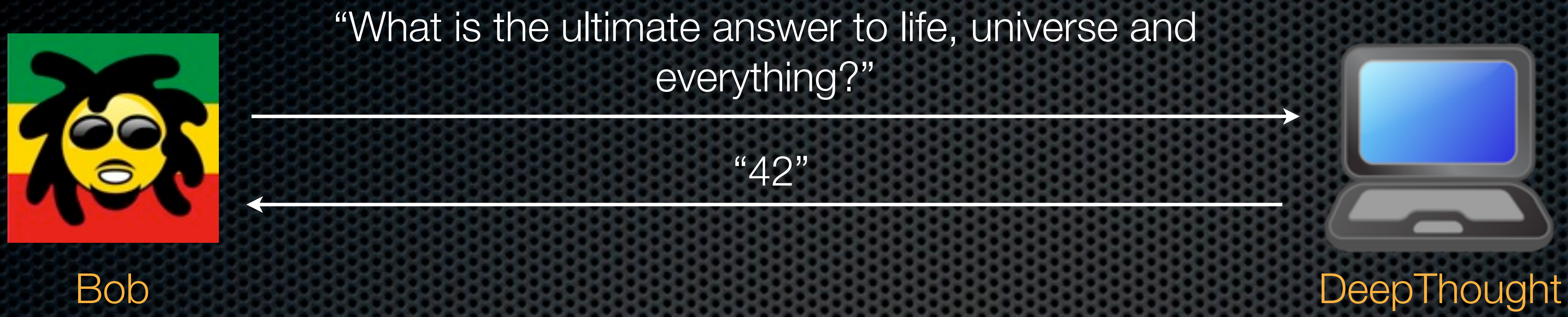

“What is the ultimate answer to life, universe and everything?”

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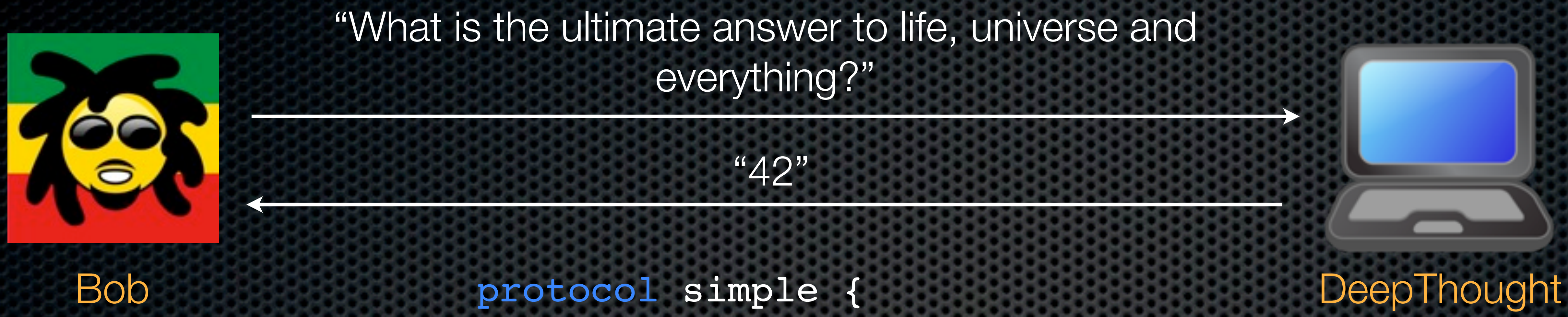

“What is the ultimate answer to life, universe and everything?”

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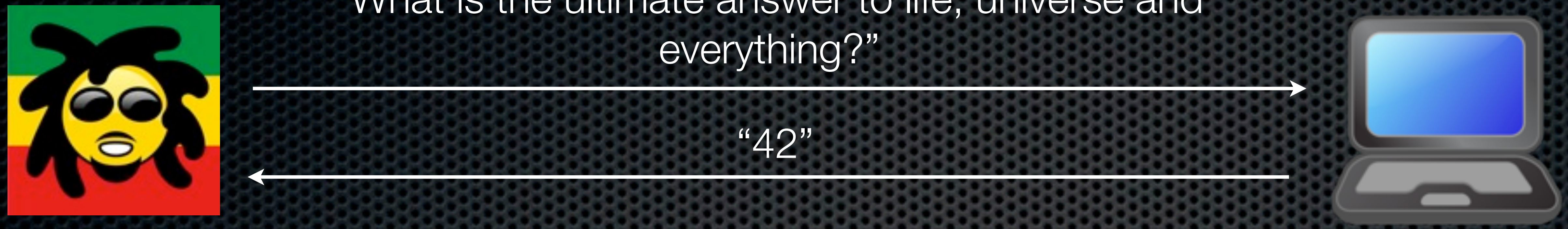
DeepThought

```
protocol simple {
  participants Bob, DeepThought;
  Bob: begin;
  Bob->DeepThought:<string>;
  DeepThought->Bob:<string>;
}
```

Global session type

Simple Example



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```
protocol simple {
  participants Bob, DeepThought;
  Bob: begin;
  Bob->DeepThought:<string>;
  DeepThought->Bob:<string>;
}
```

Global session type

```
protocol simple@Bob {
  !begin;
  DeepThought:!<string>;
  DeepThought:?<string>;
}
```

```
protocol simple@DeepThought {
  Bob:?begin;
  Bob:?<string>;
  Bob:!<string>;
}
```

Local session types

Session Implementation

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- Programmer implements the participant with Java extension for session type
- Session implementation is statically verified for conformance with local session type
- Runtime converts sends, receives and control flow actions to network transfers
- Exceptions are raised upon node and network failures

Invitation Example - Session Type

```
protocol invitation {
  participants Bob, InfoSvr, MailSvr;
  Bob: begin;
  InfoSvr->Bob: <Employer>;
  InfoSvr->Bob: <Location>;
  InfoSvr:
    [InfoSvr->Bob: <Member>;
     InfoSvr->Bob: <Employer>;
     InfoSvr->Bob: <Location>;
     InfoSvr->Bob: <EmailAddr>;
     Bob:
     {INVITE: Bob->MailSvr: <EmailAddr,Event>,
      NOOP:}
    ]*
}
```

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}
```

Recursive type

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     InfoSvr->Bob: <EmailAddr>;
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    ]*
}
```

Loop guard

Recursive type

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  participants Bob, InfoSvr, MailSvr;
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Label selection

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Choice guard

Label selection

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}
```

Multiple contiguous sends can be batched

Invitation Example - Type Driven Optimizations

```
protocol invitation {
  participants Bob, InfoSvr, MailSvr;
  Bob: begin;
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  InfoSvr:
    [InfoSvr->Bob: <Member,Employer, Location, EmailAddr>;
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}
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Can we batch together this recursive type?

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Can we batch together this recursive type?

No intervening receives by `InfoSvr` in recursive type

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- Recursive type unrolling factor is a tunable parameter

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- Recursive type unrolling factor is a tunable parameter
- Runtime handles marshaling and unmarshaling the batches

Invitation Example - Exporting Continuations

```
protocol invitation {
  participants Bob, InfoSvr, MailSvr;
  Bob: begin;
  InfoSvr->Bob: <Employer,Location>;
  InfoSvr->Bob: <Member,Employer,Location,EmailAddr>*;
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Can we bypass Bob?

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? *Can we bypass Bob?*

- Rewriting communication requests
- Cannot be exported if

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- Cannot be exported if
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? *Can we bypass Bob?*

- Rewriting communication requests
- Cannot be exported if
  - local state is accessed - file, database, system status, etc.,
  - system calls are invoked

Invitation Example - Exporting Bob’s Code

```
void invite_coworkers() {
  Event evt = me.createEvent(“party”, date);
  Employer myEmp = me.getEmployer();
  Location myLoc = me.getLocation();
  for (Member friend : me.getFriends()) {
    if (myEmp.equals(friend.getEmployer()) &&
        myLoc.equals(friend.getLocation()) &&
        User.approve(friend)) {
         mailSvr.sendMail(friend.getEmailId(),evt);
    }
  }
```

- Local state/system call ✖

Invitation Example - No Local State Access

```
void invite_coworkers’() {
  Event evt = me.createEvent(“party”, date);
  Employer myEmp = me.getEmployer();
  Location myLoc = me.getLocation();
  for (Member friend : me.getFriends()) {
    if (myEmp.equals(friend.getEmployer()) &&
        myLoc.equals(friend.getLocation())) {
         mailSvr.sendMail(friend.getEmailId(),evt);
    }
  }
```

Invitation Example - No Local State Access

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    if (myEmp.equals(friend.getEmployer()) &&
        myLoc.equals(friend.getLocation())) {
         mailSvr.sendMail(friend.getEmailId(),evt);
    }
  }
```

- Executed at `InfoSvr`

Invitation Example - No Local State Access

```
void invite_coworkers’() {
  Event evt = me.createEvent(“party”, date);
  Employer myEmp = me.getEmployer();
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  for (Member friend : me.getFriends()) {
    if (myEmp.equals(friend.getEmployer()) &&
        myLoc.equals(friend.getLocation())) {
         mailSvr.sendMail(friend.getEmailId(),evt);
    }
  }
```

- Executed at `InfoSvr`
- `me` and `friend` are local objects

Invitation Example - No Local State Access

```
void invite_coworkers’() {
  Event evt = me.createEvent(“party”, date);
  Employer myEmp = me.getEmployer();
  Location myLoc = me.getLocation();
  for (Member friend : me.getFriends()) {
    if (myEmp.equals(friend.getEmployer()) &&
        myLoc.equals(friend.getLocation())) {
         mailSvr.sendMail(friend.getEmailId(),evt);
    }
  }
```

- Executed at `InfoSvr`
- `me` and `friend` are local objects
- Only remote operation is `sendMail()`, which is also batched

Experimental Setup

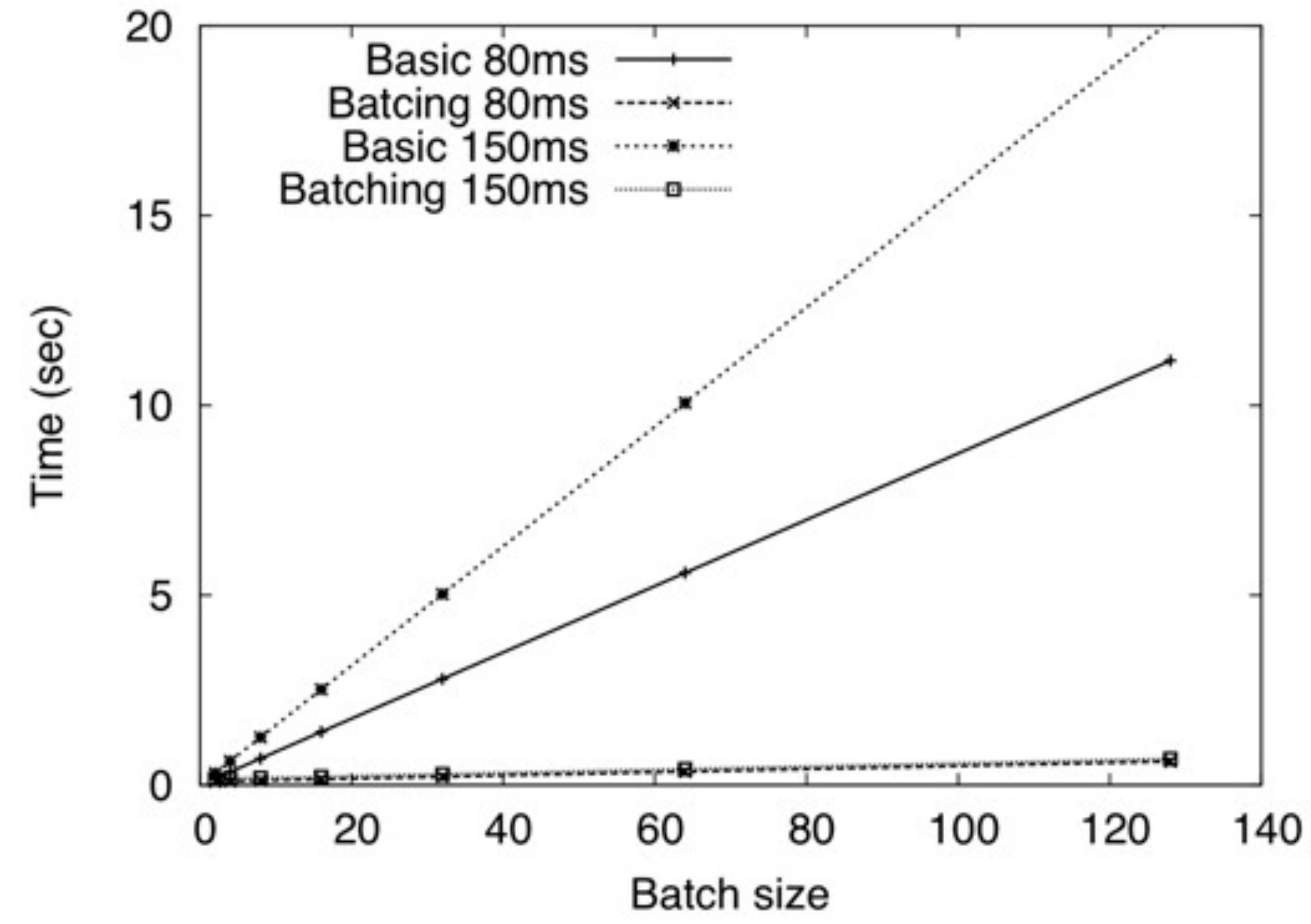
- Benchmarks
  - Batching
  - Exporting continuations
- Batching experiments were conducted on Emulab
- Emulab machines were 850 MHz Intel Pentium 3 with 512 MB of RAM

Batching

- 2 Emulab nodes with 1MBPS link.

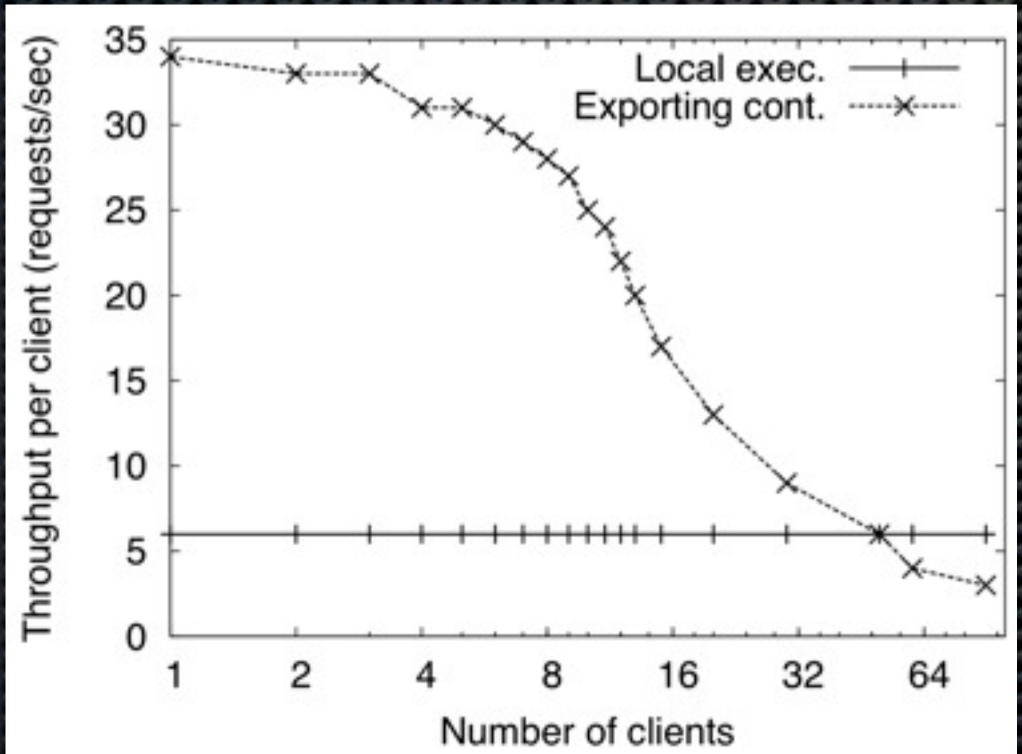
```
client:
[client->server: <Signature>;
 server->client: <bool>]*
```

- Tested for various RTT and signature sizes
- Batching performs well and the overhead is very little

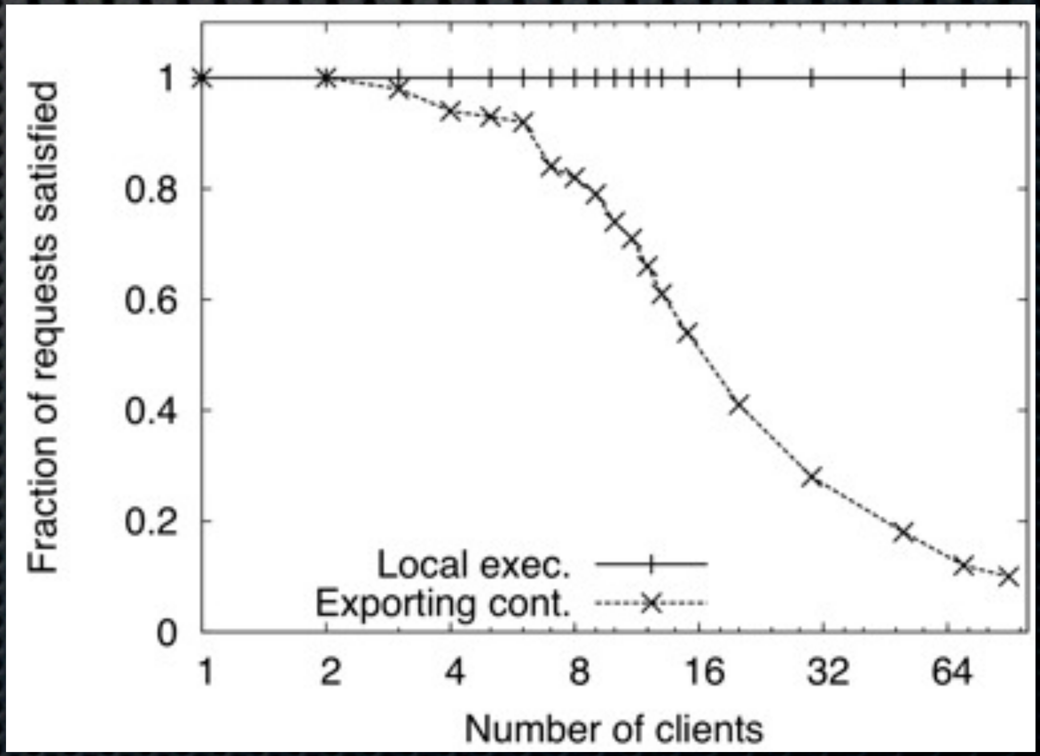


Exporting Continuation

- Algorithmic trading
  - Remote methods - `fetchQuotes()` and `doTrading()`
  - Local/exported method - `findTradingOptions()`
- Server configuration - dual core machine - 3 GHz and 4GB RAM
- Client configuration - Intel Pentium II 500 MHz



client throughput



server throughput

Conclusion

- Limitations
  - Aggressive continuation exporting can overload participants
  - Security issues with client code executing on the server
- Future Work
  - User annotations for continuation exporting
  - Group communication abstraction
  - Formally prove that the transformations are correct

Questions?

Extra slides - Session Implementation

```
protocol simple@Bob{
   !begin;
   DeepThought:!<string>;
   DeepThought:?<int>;
}
```

Extra slides - Session Implementation

```
SessionRegistry.instantiate(simple,“session1”);
```

```
protocol simple@Bob{
  !begin;
  DeepThought:!<string>;
  DeepThought:?<int>;
}
```

Extra slides - Session Implementation

```
protocol simple@Bob{
   !begin;
   DeepThought:!<string>;
   DeepThought:?<int>;
}
```

```
SessionRegistry.instantiate(simple,“session1”);
SessionSocket ss =
   SessionRegistry.lookup(simple,“session1”,Bob);
```

Extra slides - Session Implementation

```
protocol simple@Bob{
  !begin;
  DeepThought:!<string>;
  DeepThought:?<int>;
}
```

```
SessionRegistry.instantiate(simple,“session1”);
SessionSocket ss =
   SessionRegistry.lookup(simple,“session1”,Bob);
ss.begin ();
```

Extra slides - Session Implementation

```
protocol simple@Bob{
  !begin;
  DeepThought:!<string>;
  DeepThought:?<int>;
}
```

```
SessionRegistry.instantiate(simple,“session1”);
SessionSocket ss =
   SessionRegistry.lookup(simple,“session1”,Bob);
ss.begin ();
ss.send (DeepThought, “what is the ultimate
   answer to life, universe, and everything?”);
```

Extra slides - Session Implementation

```
protocol simple@Bob{
  !begin;
  DeepThought:!<string>;
  DeepThought:?<int>;
}
```

```
SessionRegistry.instantiate(simple,“session1”);
SessionSocket ss =
   SessionRegistry.lookup(simple,“session1”,Bob);
ss.begin ();
ss.send (DeepThought, “what is the ultimate
   answer to life, universe, and everything?”);
int answer = ss.receive (DeepThought);
```