KTH ROYAL INSTITUTE
OF TECHNOLOGY

Remote Invocation

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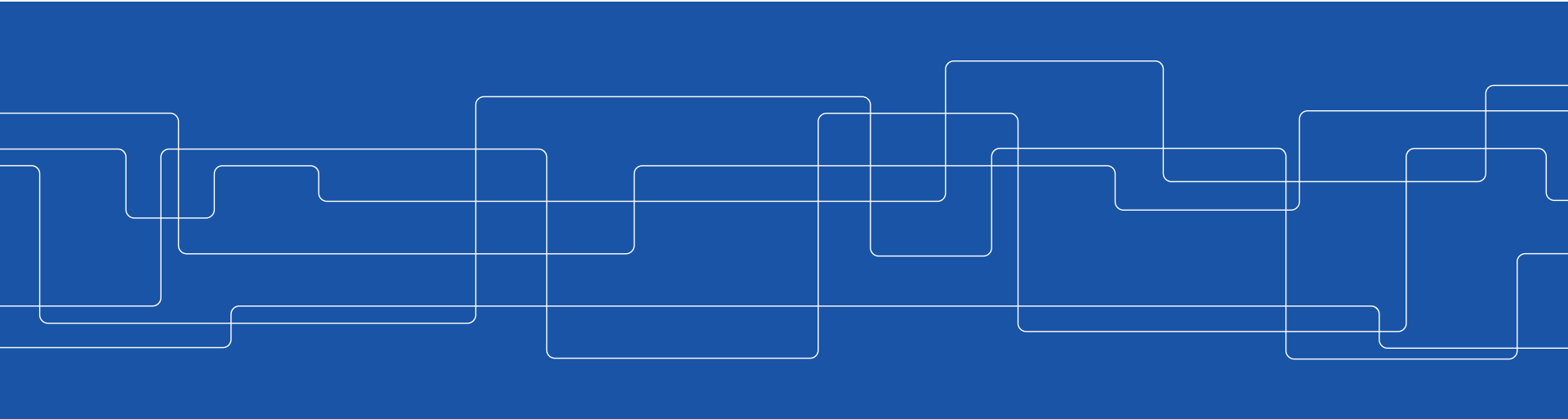
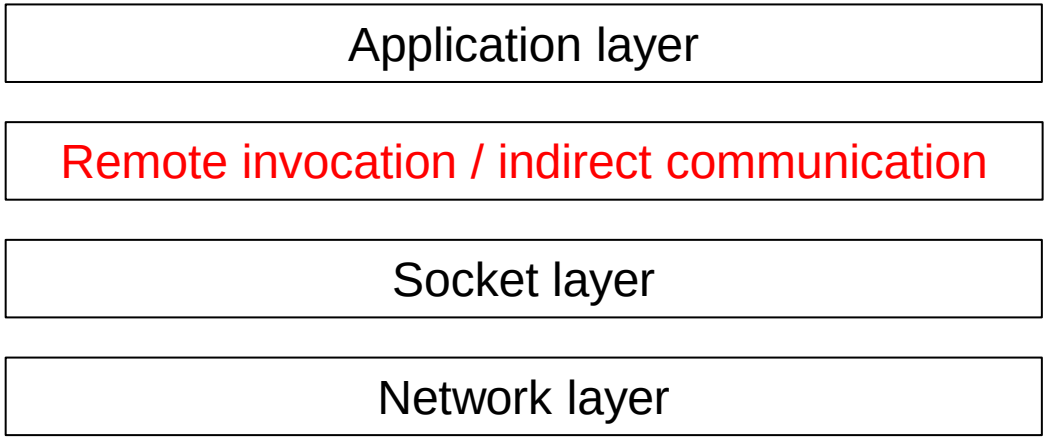
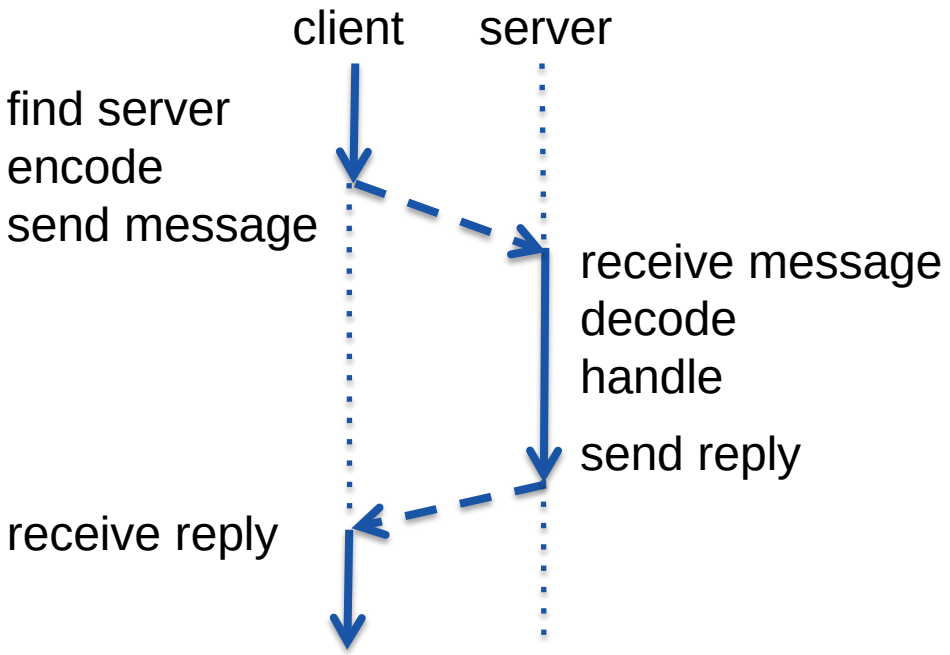


Middleware

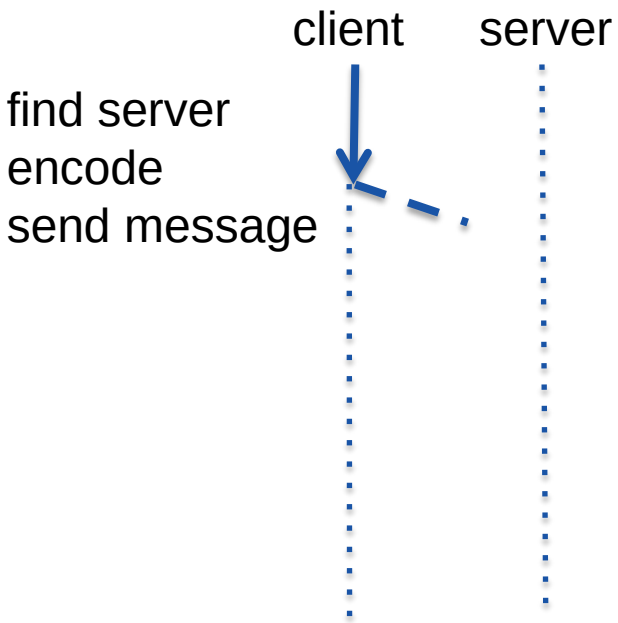

Application layer
Remote invocation / indirect communication
Socket layer
Network layer

Request / Reply



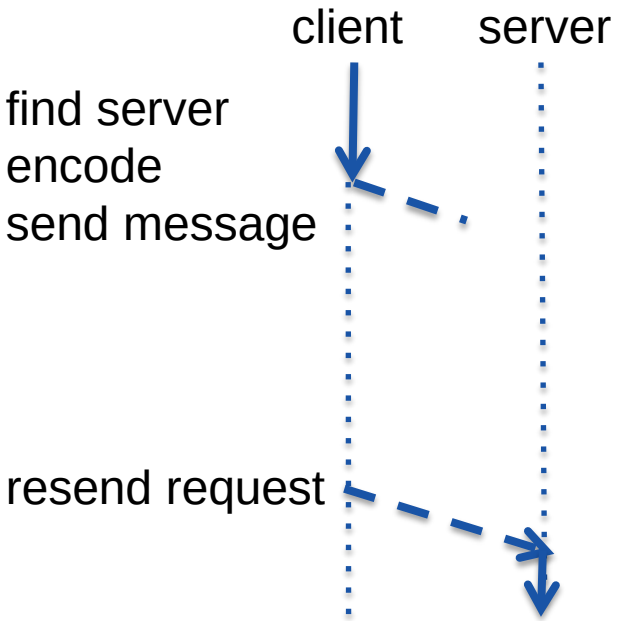
- identify and locate the server
- encode/decode the message
- send reply to the right client
- attach reply to request

Lost request



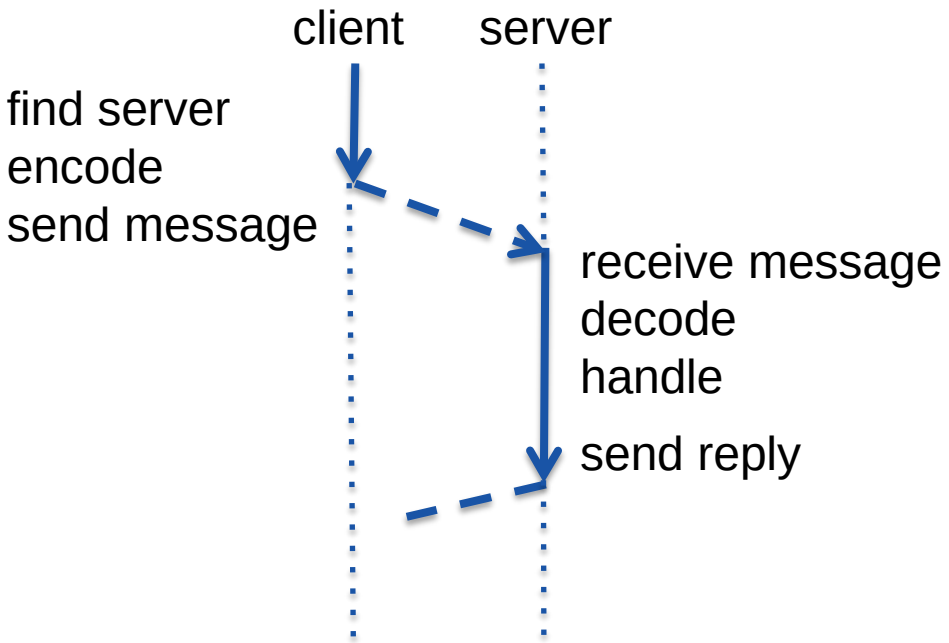
What do we do if request is lost?

Resend request



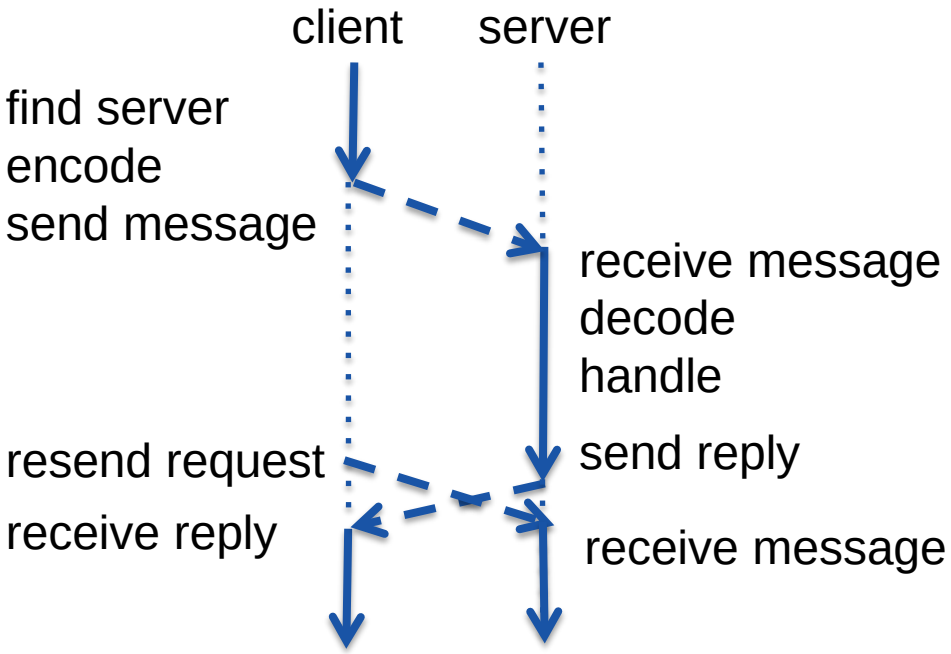
- need to detect that message is potentially lost
- wait for a timeout (how long) or error from underlying layer
- resend the request
- simple, problem solved

Lost reply



- client will wait for timeout and re-send request
- not a problem

Problem



- a problem
- server might need a history of all previous request
- *might need*

Idempotent operations

- add 100 euros to my account
- what is the status of my account
- Sweden scored yet another goal!
- The standing is now 2-1!

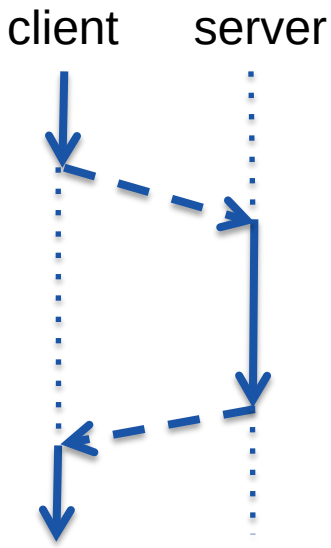
History

If operations are not idempotent, the server must make sure that the same request is not executed twice.

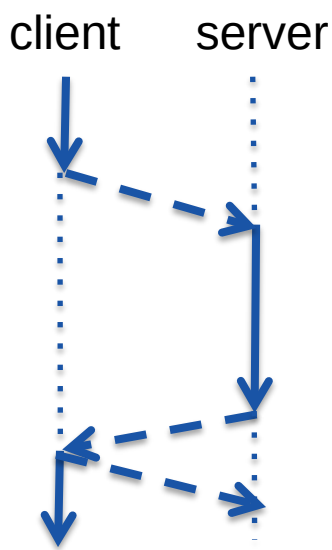
Keep a history of all request and the replies. If a request is resent the same reply can be sent without re-execution.

For how long do you keep the history?

Request-Reply-Acknowledge



Request-Reply (RR)



Request-Reply-Acknowledge (RRA)

At-most-once or At-least-once

How about this:

If an operation succeeds, then..

at-most-once: the request has been executed once.

Implemented using a history or simply not re-sending requests.

at-least-once: the request has been executed at least once.

No need for a history, simply resend requests until a reply is received.

At most or At least

How about errors:

Even if we do resend messages we will have to give up at some time.

If an operation fails/is lost, then..

at-most-once:

at-least-once:

At most or At least

Pros and cons:

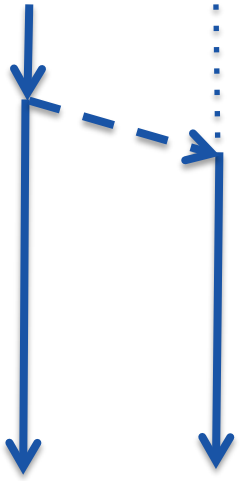
- *at-most-once without re-sending requests:*
  simple to implement, not fault-tolerant
- *at-most-once with history:*
  expensive to implement, fault-tolerant
- *at-least-once:*
  simple to implement, fault-tolerant

Can you live with at-least-once semantics?

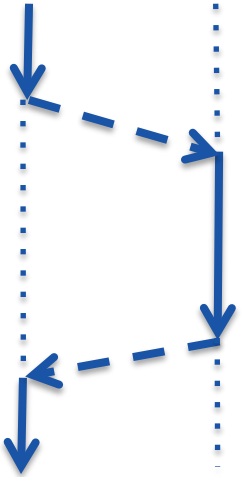
UDP or TCP

Should we implement a request-reply protocol over UDP or TCP?

Synchronous or Asynchronous

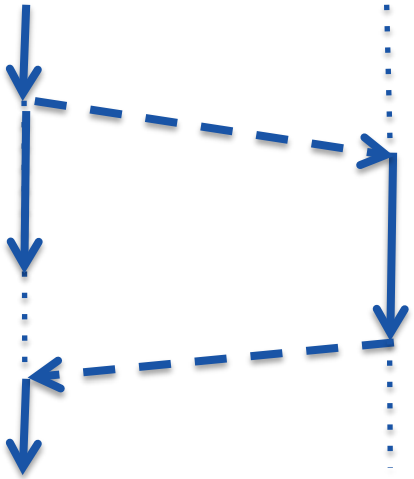


Asynchronous



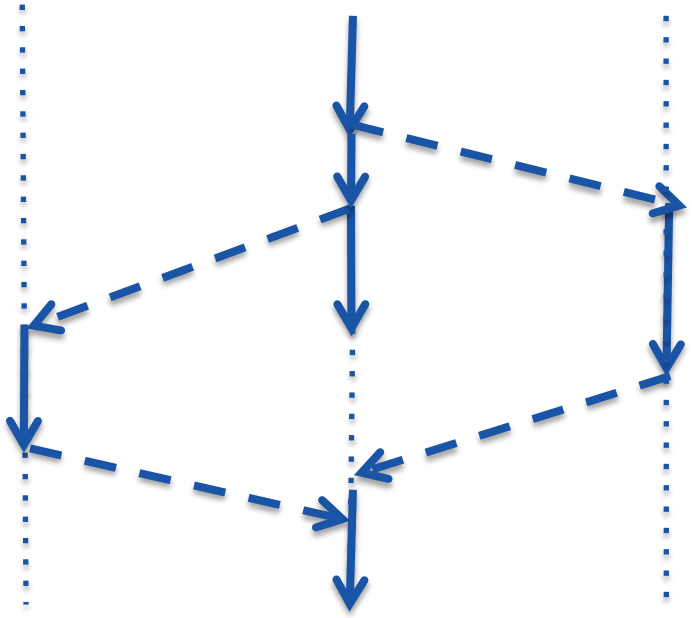
Synchronous

RR over Asynchronous



- send request
- continue to execute
- suspend if not arrived
- read reply

Hide the latency



HTTP

A request reply protocol, described in RFC 2616.

Request = Request-Line *(header CRLF) CRLF [message-body]

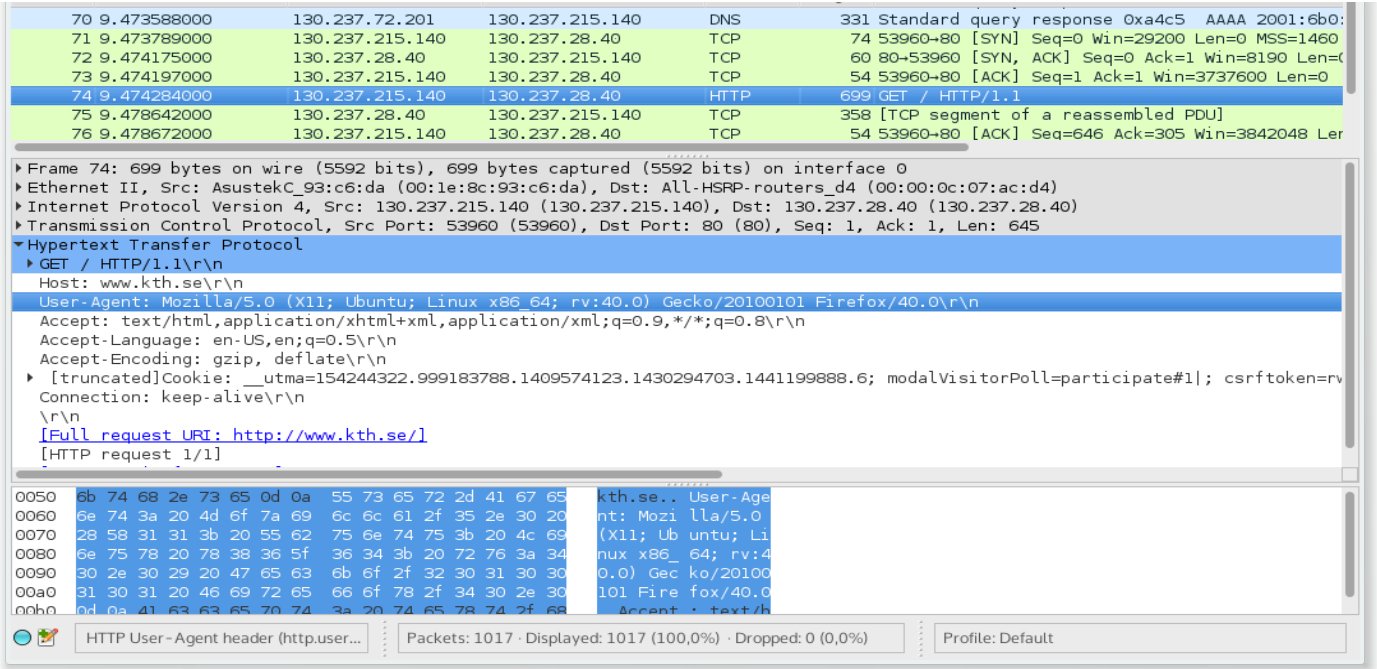
Request-Line = Method SP Request-URI SP HTTP-Version CRLF

GET /index.html HTTP/1.1\r\n foo 42 \r\n\r\nHello

HTTP methods

- **GET**: request a resource, *should be idempotent*
- **HEAD**: request only header information
- **POST**: upload information to a resource, included in body, status of server could change
- **PUT**: add or replace a resource, idempotent
- **DELETE**: add or replace content, idempotent

Wireshark


70 9.473588000 130.237.72.201 130.237.215.140 DNS 331 Standard query response 0xa4c5 AAAA 2001:6b0:
71 9.473789000 130.237.215.140 130.237.28.40 TCP 74 53960→80 [SYN] Seq=0 Win=29200 Len=0 MSS=1460
72 9.474175000 130.237.28.40 130.237.215.140 TCP 60 80→53960 [SYN, ACK] Seq=0 Ack=1 Win=8190 Len=0
73 9.474197000 130.237.215.140 130.237.28.40 TCP 54 53960→80 [ACK] Seq=1 Ack=1 Win=3737600 Len=0
74 9.474284000 130.237.215.140 130.237.28.40 HTTP 699 GET / HTTP/1.1
75 9.478642000 130.237.28.40 130.237.215.140 TCP 358 [TCP segment of a reassembled PDU]
76 9.478672000 130.237.215.140 130.237.28.40 TCP 54 53960→80 [ACK] Seq=646 Ack=305 Win=3842048 Len
Frame 74: 699 bytes on wire (5592 bits), 699 bytes captured (5592 bits) on interface 0
Ethernet II, Src: AsustekC_93:c6:da (00:1e:8c:93:c6:da), Dst: All-HSRP-routers_d4 (00:00:0c:07:ac:d4)
Internet Protocol Version 4, Src: 130.237.215.140 (130.237.215.140), Dst: 130.237.28.40 (130.237.28.40)
Transmission Control Protocol, Src Port: 53960 (53960), Dst Port: 80 (80), Seq: 1, Ack: 1, Len: 645
Hypertext Transfer Protocol
GET / HTTP/1.1\r\n
Host: www.kth.se\r\n
User-Agent: Mozilla/5.0 (X11; Ubuntu; Linux x86_64; rv:40.0) Gecko/20100101 Firefox/40.0\r\n
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8\r\n
Accept-Language: en-US,en;q=0.5\r\n
Accept-Encoding: gzip, deflate\r\n
[truncated]Cookie: __utma=154244322.999183788.1409574123.1430294703.1441199888.6; modalVisitorPoll=participate#1|; csrftoken=rv
Connection: keep-alive\r\n
\r\n
[Full request URI: http://www.kth.se/]
[HTTP request 1/1]
0050 6b 74 68 2e 73 65 0d 0a 55 73 65 72 2d 41 67 65 kth.se.. User-Age
0060 6e 74 3a 20 4d 6f 7a 69 6c 6c 61 2f 35 2e 30 20 nt: Mozi lla/5.0
0070 28 58 31 31 3b 20 55 62 75 6e 74 75 3b 20 4c 69 (X11; Ub untu; Li
0080 6e 75 78 20 78 38 36 5f 36 34 3b 20 72 76 3a 34 nux x86_ 64; rv:4
0090 30 2e 30 29 20 47 65 63 6b 6f 2f 32 30 31 30 30 0.0) Gec ko/20100
00a0 31 30 31 20 46 69 72 65 66 6f 78 2f 34 30 2e 30 101 Fire fox/40.0
HTTP User-Agent header (http.user...
Packets: 1017 · Displayed: 1017 (100,0%) · Dropped: 0 (0,0%)
Profile: Default

HTTP GET

GET / HTTP/1.1

Host: www.kth.se

User-Agent: Mozilla/5.0 (X11; Ubuntu; Linux x86_64; rv:40.0) Gecko/20100101

Accept: text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8

Accept-Language: en-US,en;q=0.5

Accept.Encoding: gzip, deflate

Cookie: .....

Connection: keep-alive

HTTP Response

```
HTTP/1.1 200 OK
Date: Tue, 08 Sep 2015 10:37:49 GMT
Server: Apache/2.2.15 (Red Hat)
X-UA-Compatible: IE=edge
Set-Cookie: JSESSIONID=CDC76A3;Path=/; Secure; HttpOnly
Content-Language: sv-SE
Content-Length: 59507
Connection: close
Content-Type: text/html;charset=UTF-8
<!DOCTYPE html>
<html lang="sv">
<title>KTH | Valkommen till KTH</title>
```

The web

On the web the resource is often a HTML document that is presented in a browser.

HTTP could be used as a general-purpose request-reply protocol.

REST and SOAP

Request-reply protocols for Web-services:

- **REST (Representational State Transfer)**
  - content described in XML, JSON, . . .
  - light weight,
- **SOAP (Simple Object Access Protocol)**
  - over HTTP, SMTP . . .
  - content described in SOAP/XML
  - standardized, heavy weight

HTTP over TCP

HTTP over TCP - a good idea?

Masking a request-reply

Could we use a regular program construct to hide the fact that we do a request-reply?

Masking a request-reply

Could we use a regular program construct to hide the fact that we do a request-reply?

- **RPC**: Remote Procedure Call
- **RMI**: Remote Method Invocation

Procedure calls

What is a procedure call:

- find the procedure
- give the procedure access to arguments
- pass control to the procedure
- collect the reply if any
- continue execution

How do we turn this into a tool for distributed programming?

Operational semantics

```
int x, n;
n = 5;
proc(n);
x = n;
```

```
int x, arr[3];
arr[0] = 5;
proc(arr);
x = arr[0];
```

Call by value/reference

Call by value

- A procedure is given a copy of the datum

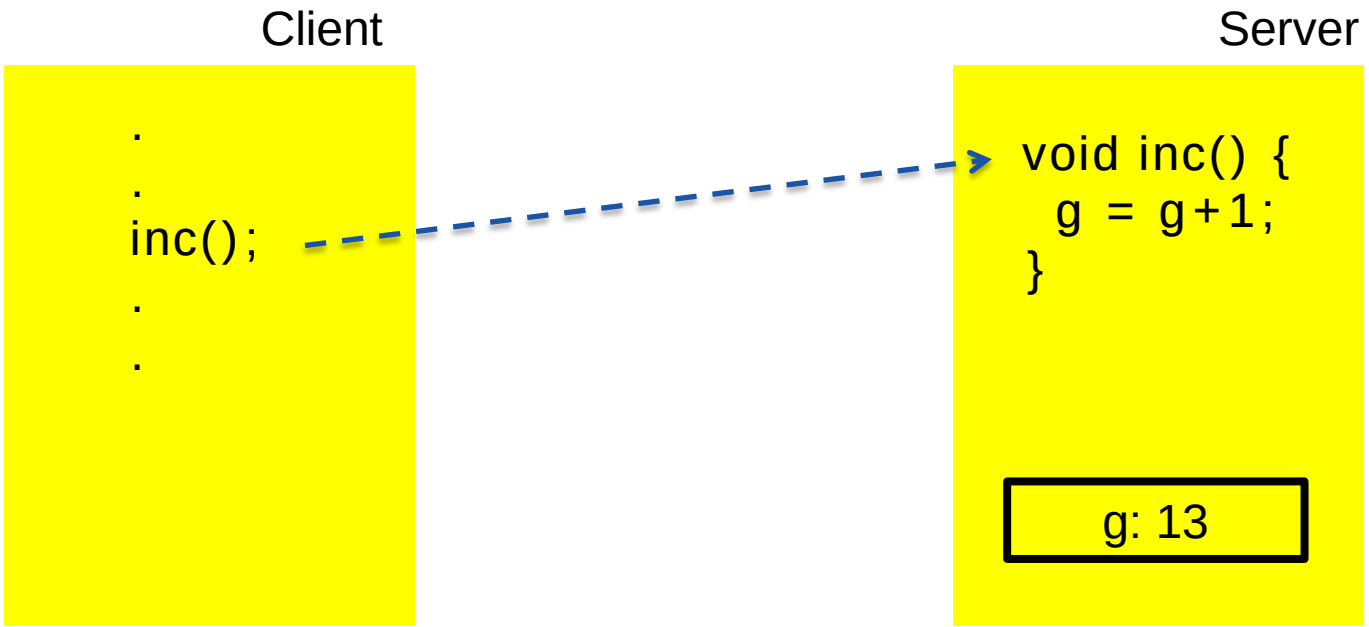
Call by reference

- A procedure is given a reference to the datum

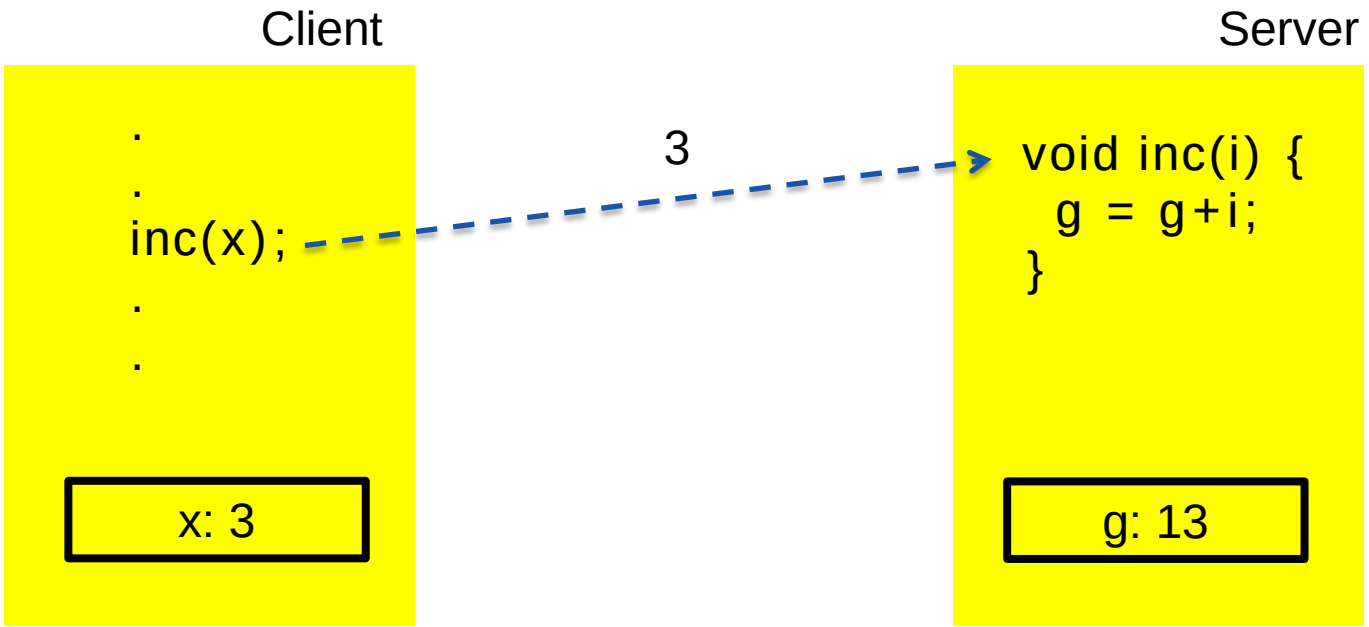
What if the datum is a reference and we pass a copy of the datum?

Why is this important?

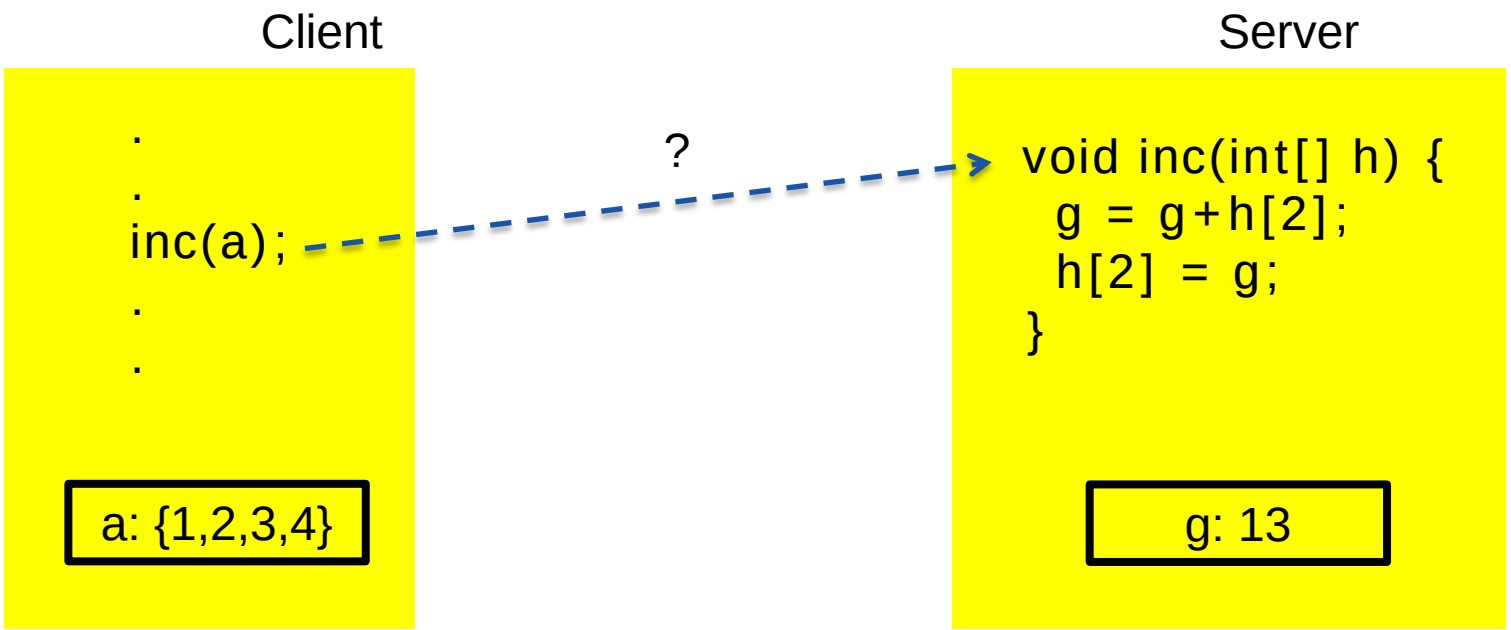
RPC: Remote Procedure Call



RPC: Remote Procedure Call



RPC: Remote Procedure Call



Open Network Computing (ONC) RPC (SunRPC)

- targeting intranet, file servers etc
- at-least-once call semantics
- procedures described in Interface Definition Language (IDL)
- XDR (eXternal Data Representation) specifies message structure
- used UDP as transport protocol (TCP also available)

Java RMI (Remote Method Invocation)

- similar to RPC but:
  - we now invoke methods of remote objects
  - at-most-once semantics

- Objects can be passed as arguments, how should this be done?
  - by value
  - by reference

Java RMI

We can do either:

A *remote object* is passed as a reference (*by reference*) i.e. it remains as at the original place where it was created.

A *serializable object* is passed as a copy (*by value*) i.e. the object is duplicated.

Finding the procedure/object

How do we locate a remote procedure/object/process?

Network address that specifies the location or..

a known “binder” process that keeps track of registered resources.

Remote invocation design decisions

- failure handling: maybe / at-most-once / at-least-once
- call-by-value / call-by-reference
- message specification and encoding
- specification of resource
- procedure binder

Examples

- SunRPC: call-by-value, at-least-once, IDL, XDR, binder
- JavaRMI: call-by-value/reference, at-most-once, interface, JRMP (Java Remote Method Protocol), rmiregistry
- Erlang: message passing, maybe, no, ETF (External Term Format), local registry only
- CORBA (Common Object Request Broker Architecture): call-by-reference, IDL, ORB (Object Request Broker), tnameserv
- Web Services: WSDL (Web Services Description Language), UDDI (Universal Description, Discovery, and Integration)

Summary

Implementations of remote invocations: procedures, methods, messages to processes,
have fundamental problems that needs to be solved.

Try to see similarities between different implementations.

When they differ, is it fundamentally different or just implementation details.