Client/Server paradigm

ARCOS Group

Distributed Systems

Bachelor In Informatics Engineering

Universidad Carlos III de Madrid

A simple definition

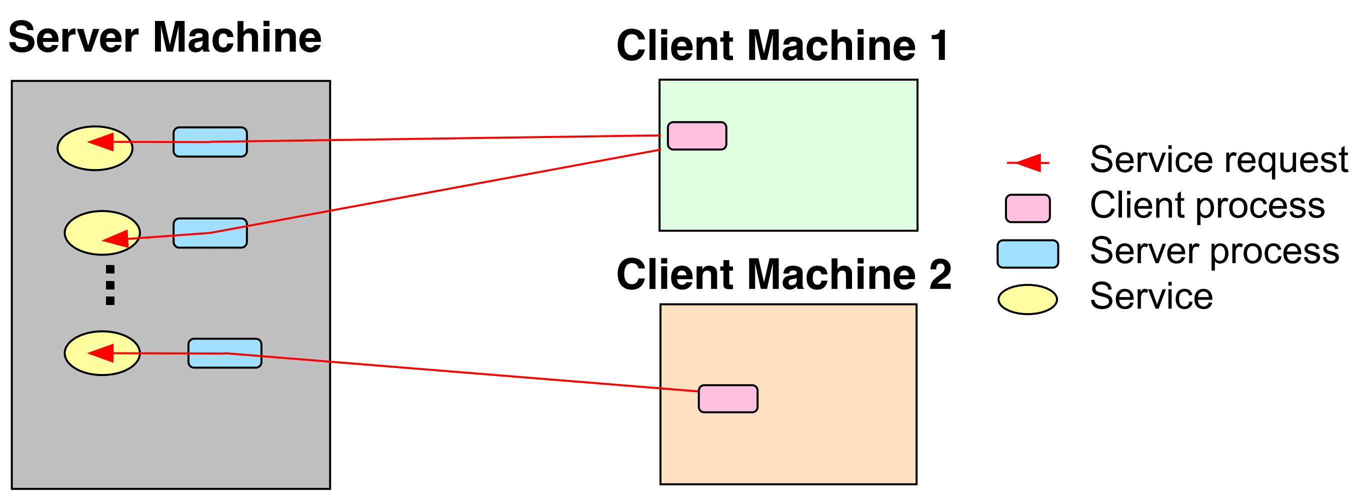
" Server software accepts requests for data from client software and returns the results to the client"

Where are operations executed

- Most of the application processing is done on a computer (client side)
- …which obtains application services (such as database services) from another computer (server side) in a master slave configuration

Client/Server paradigm

- Asigns different roles to the communicating processes
- Server:
  - Offers services
  - Passive: waits for incoming requests from clients
- Client:
  - Requests services
  - Active: sends requests to server(s)



Servers may be…

- Depending on the type of connection with the client:
  - Connection-oriented
  - Connectionless
- Depending on the number of serviced client sessions:
  - Sequential: if it communicates with a single client session at the time
  - Concurrent: if it may communicate with multiple client sessions at the time
- Depending on whether it stores communication state:
  - Stateful
  - Stateless

Connection-oriented servers

- Client and server must establish a connection (logical or physical) before communicating; when finalizing the communication they must close the connection
- Once the connection established it isn't necessary to refer directly to the sender and receiver
- C-O protocols may be seen as stateful – keep track of conversation
- May not serve new client before current one closes the connection!
- E.g.: TCP

Connectionless servers

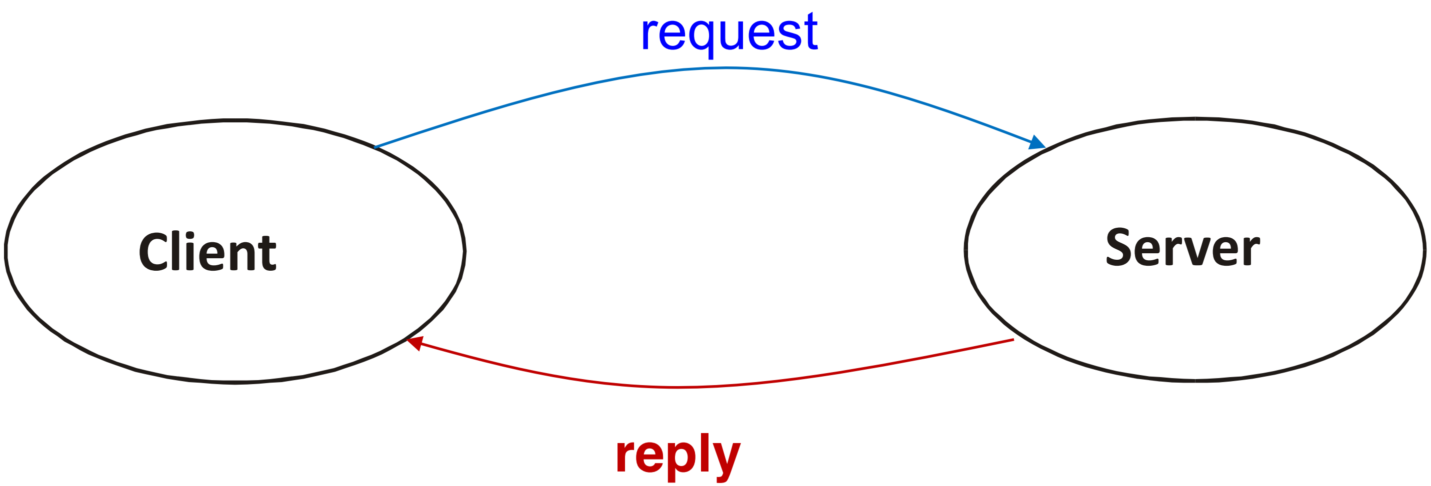
- Data exchanged via self-contained packets which must contain explicit server/client address information
  - No previous agreement
- C-less protocols may be seen as stateless
- May interleave different client requests!
- E.g.: IP, UDP

What is a session?

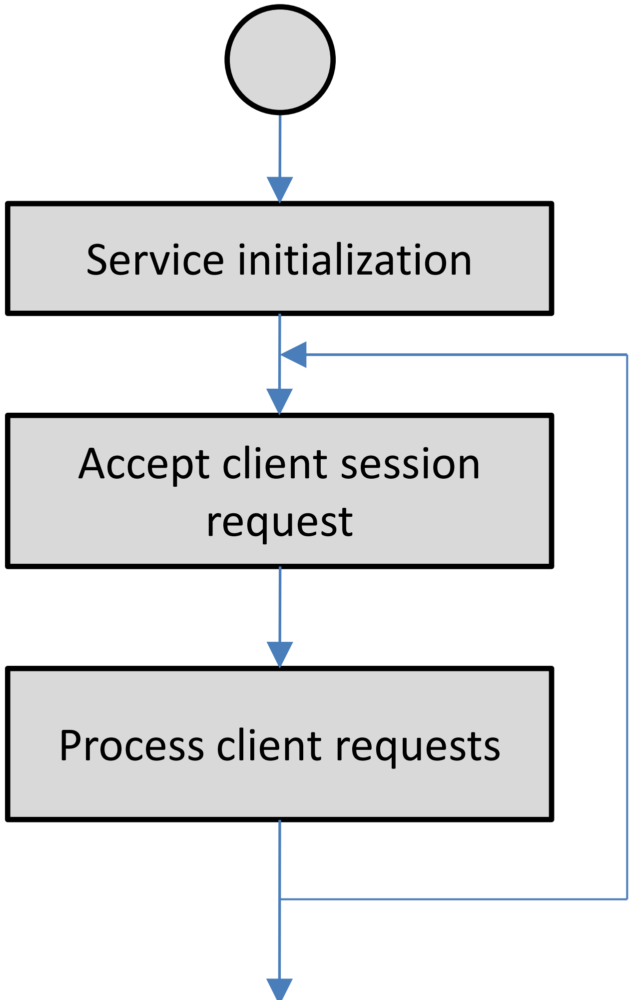
- Session: Interaction between client and server until client gets the requested service
- The server runs an infinit loops which accepts service requests from client sessions
- A service protocol specifies the rules that the client and server follow during a session wrt:
  - Naming a service: services identify themselves via a registered logical name or the server physical process address (machine name + port number)
  - Communication sequence
  - Data representation

Sequential servers

- Serves client requests sequentially
- Does not interleave requests from multiple client sessions
- While attending to a client seesion all others must wait

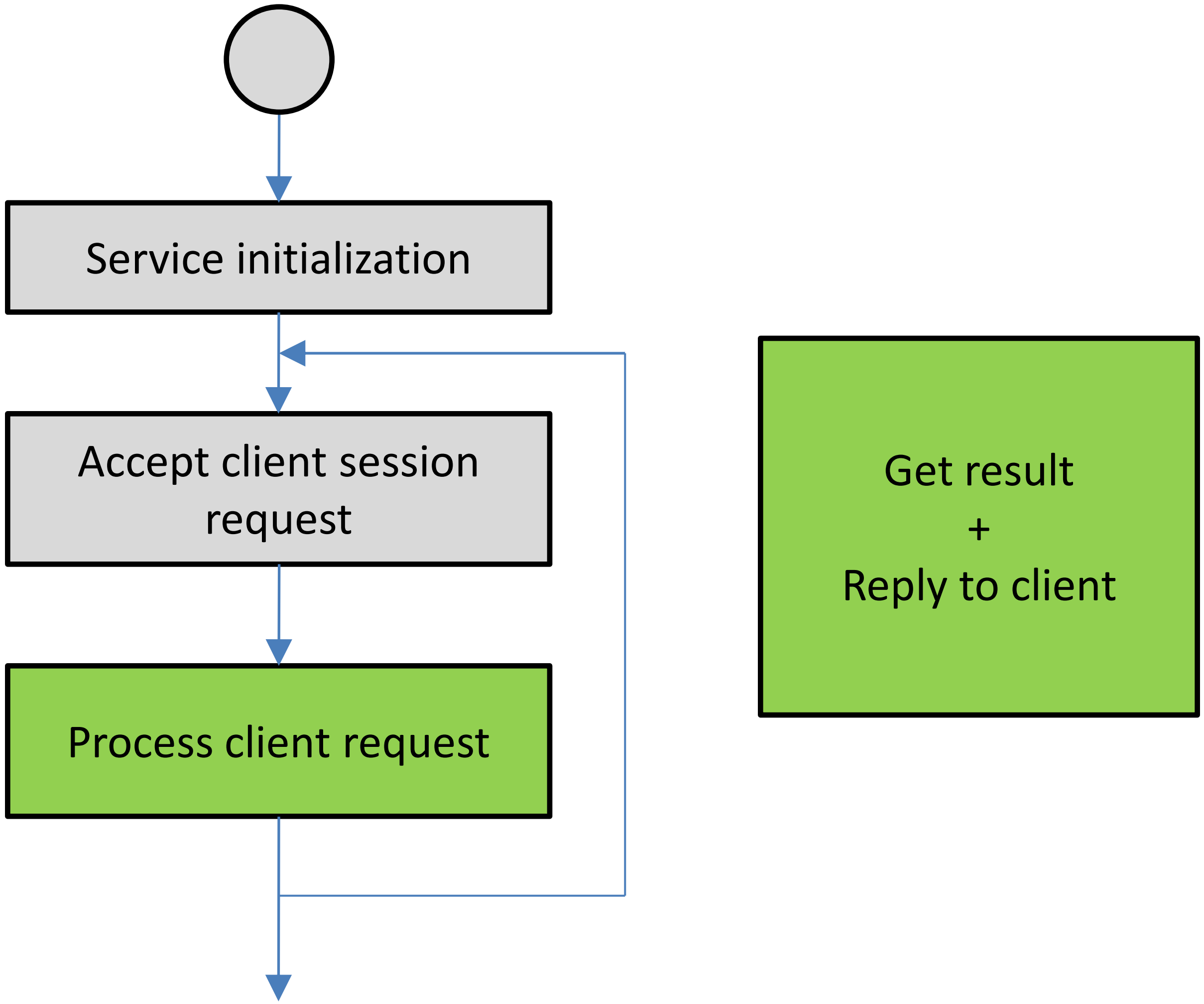


Execution flow



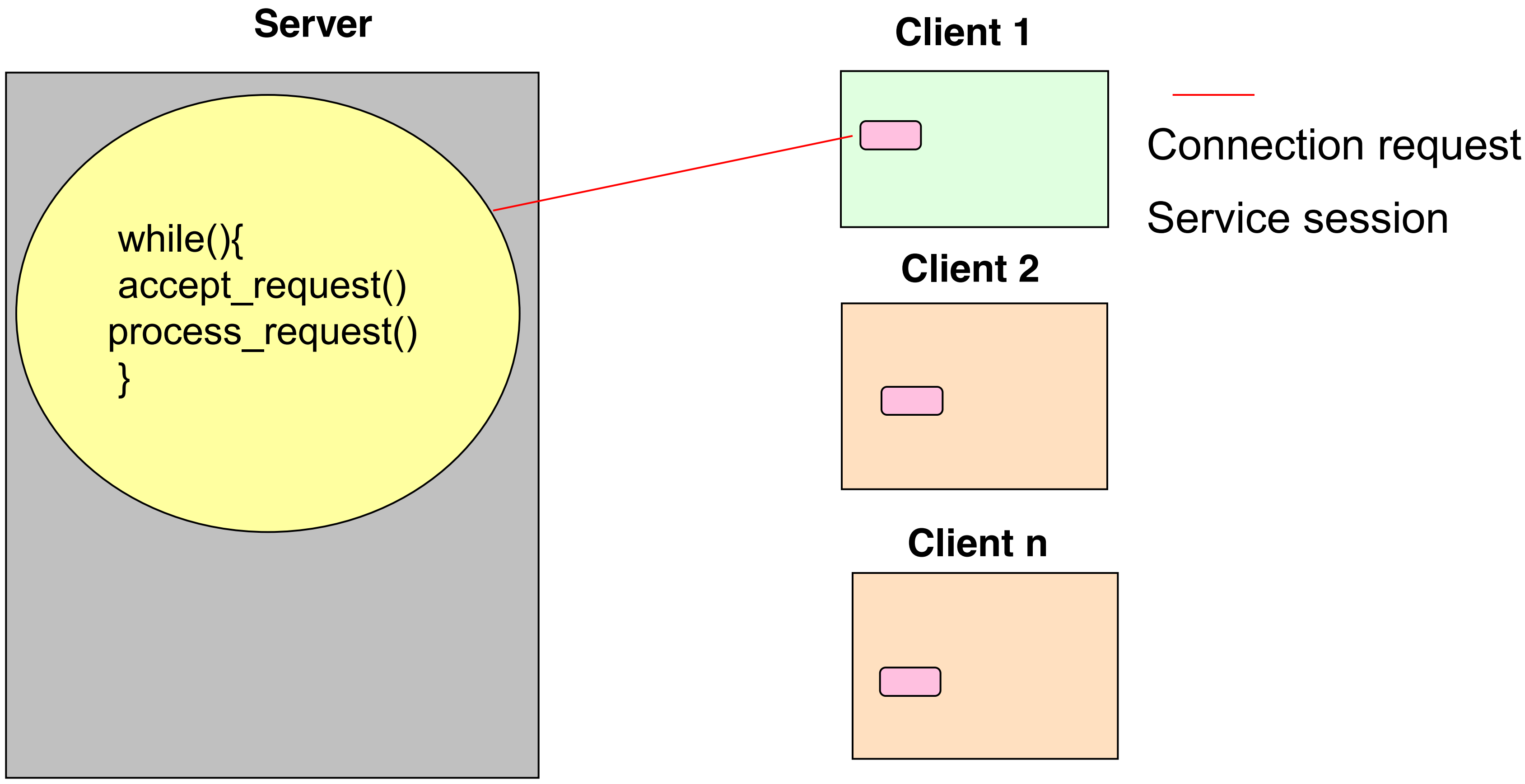
If for each client i keep a service session this server is sequential!

Execution flow

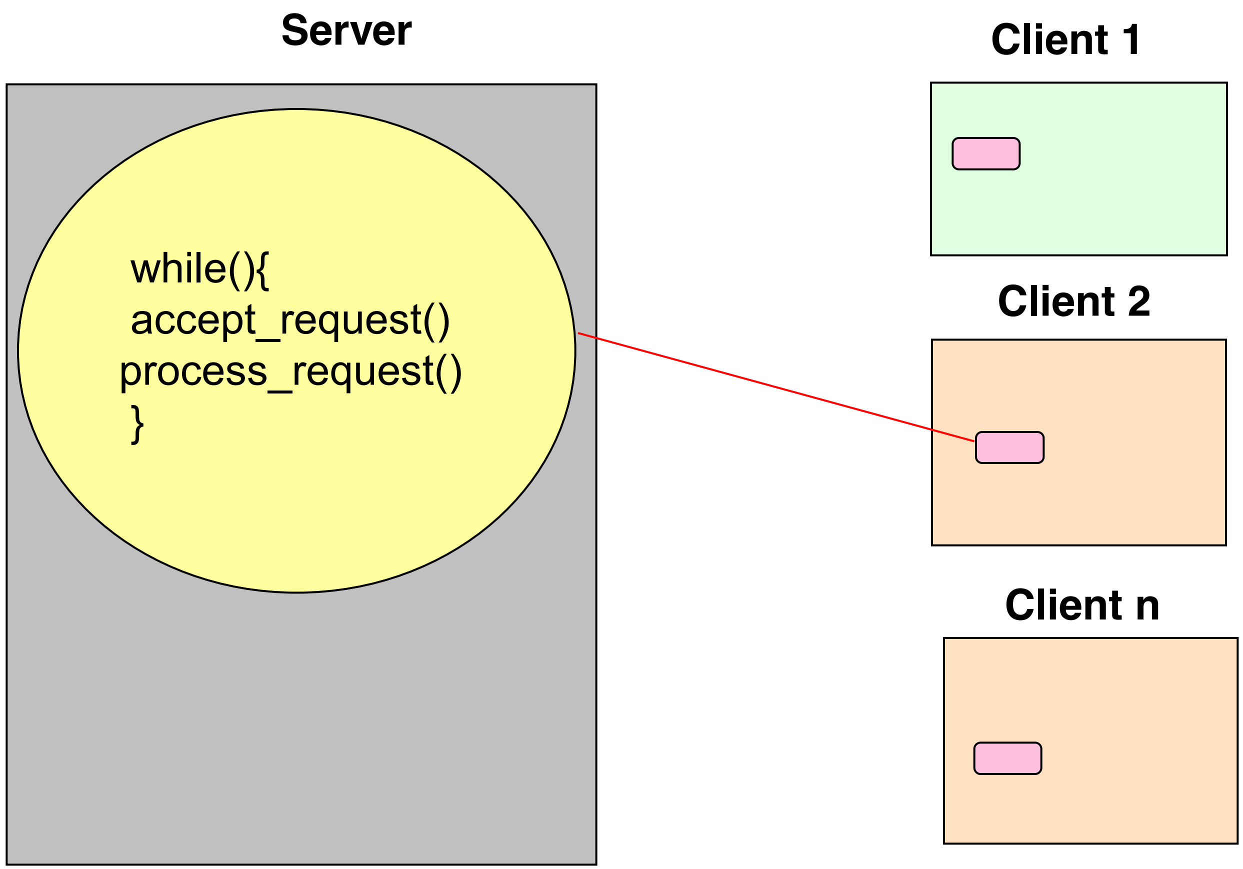


Sequential server

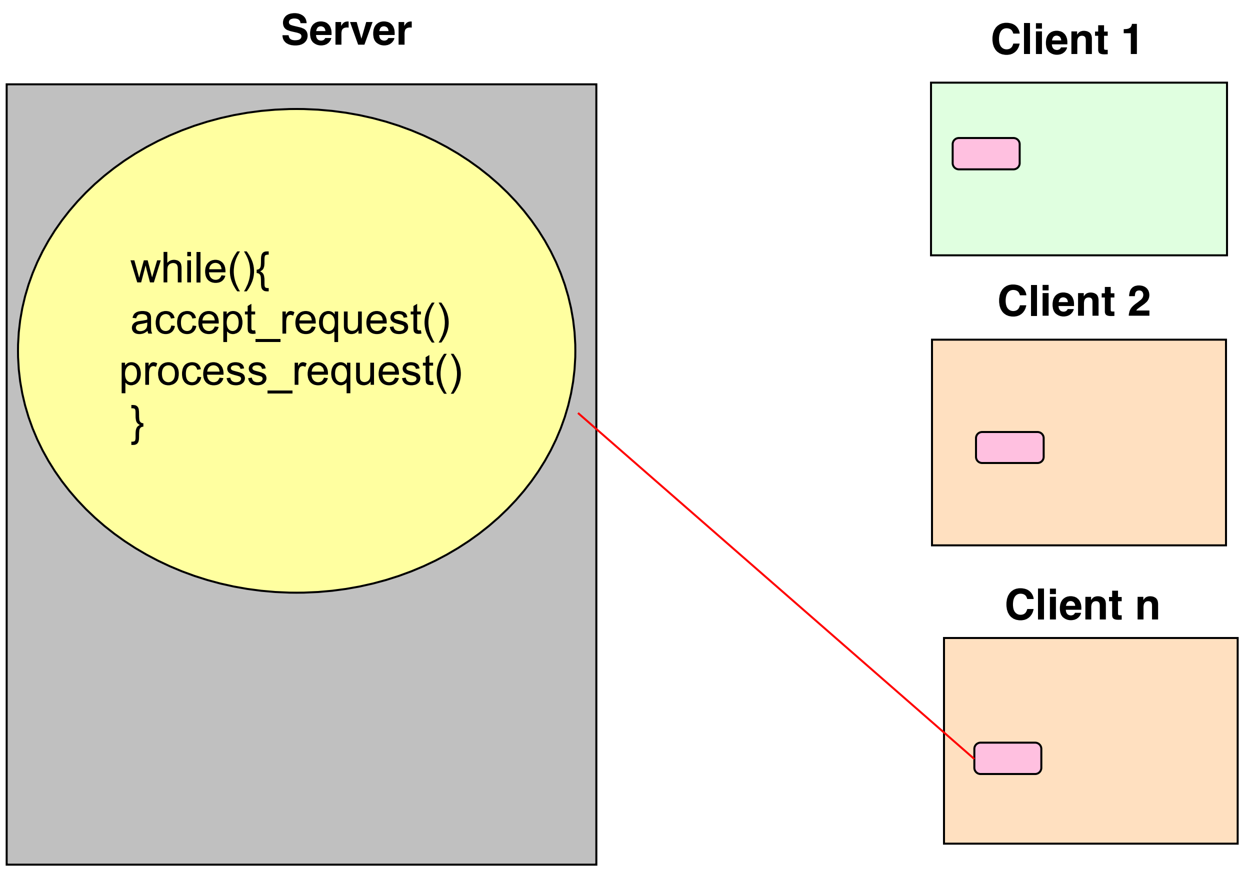
Sequential Client/Server



Sequential Client/Server

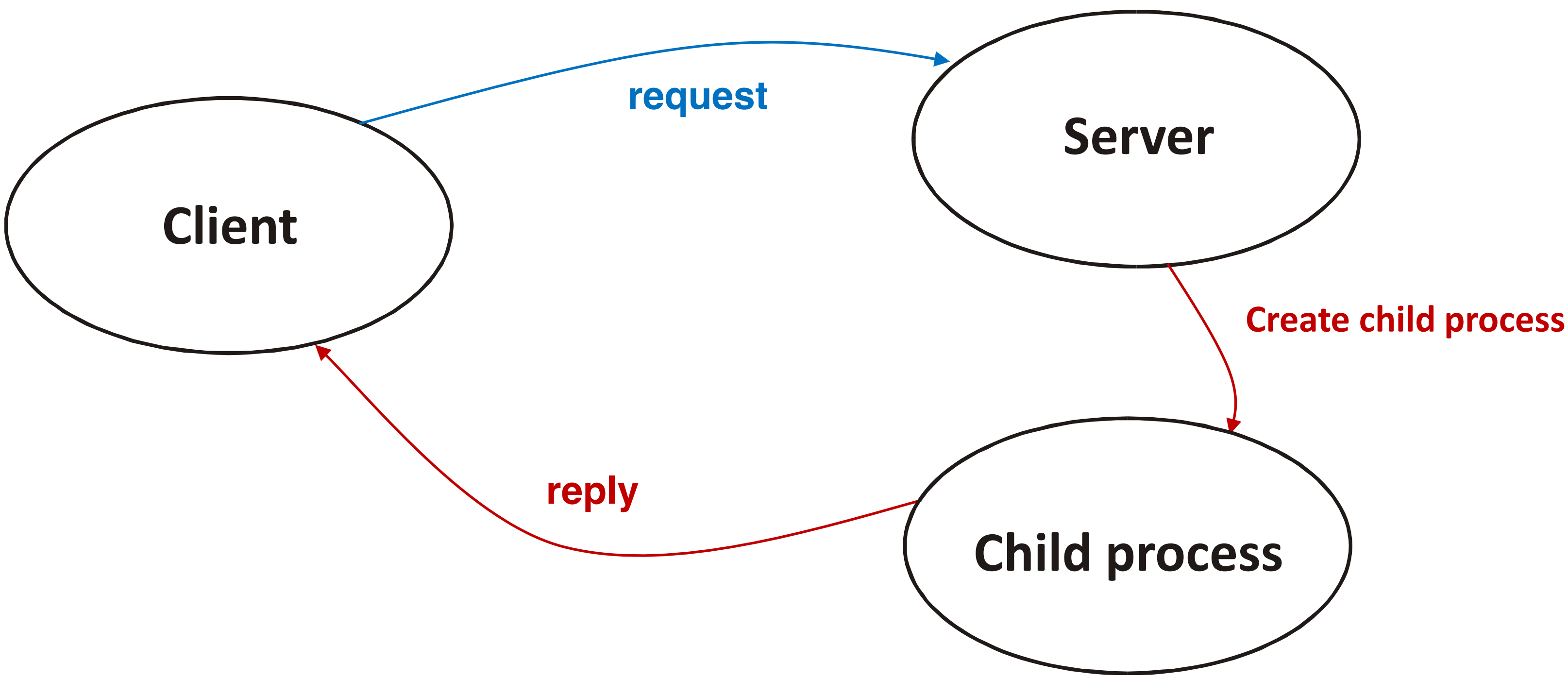


Sequential Client/Server



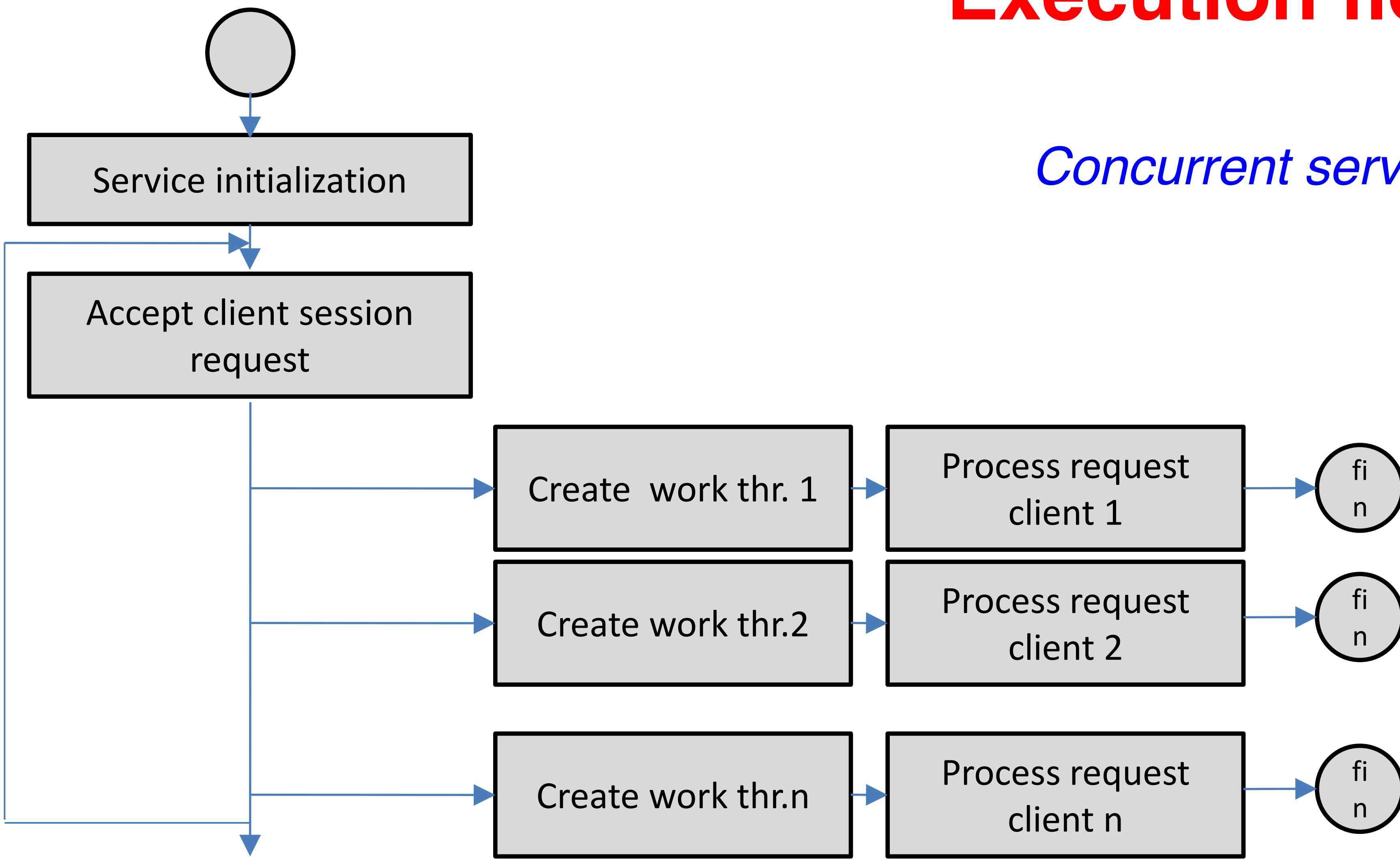
Concurrent servers

- Server creates a child process which will process the request and send the reply to the client
- Multiple client sessions may be interleaved



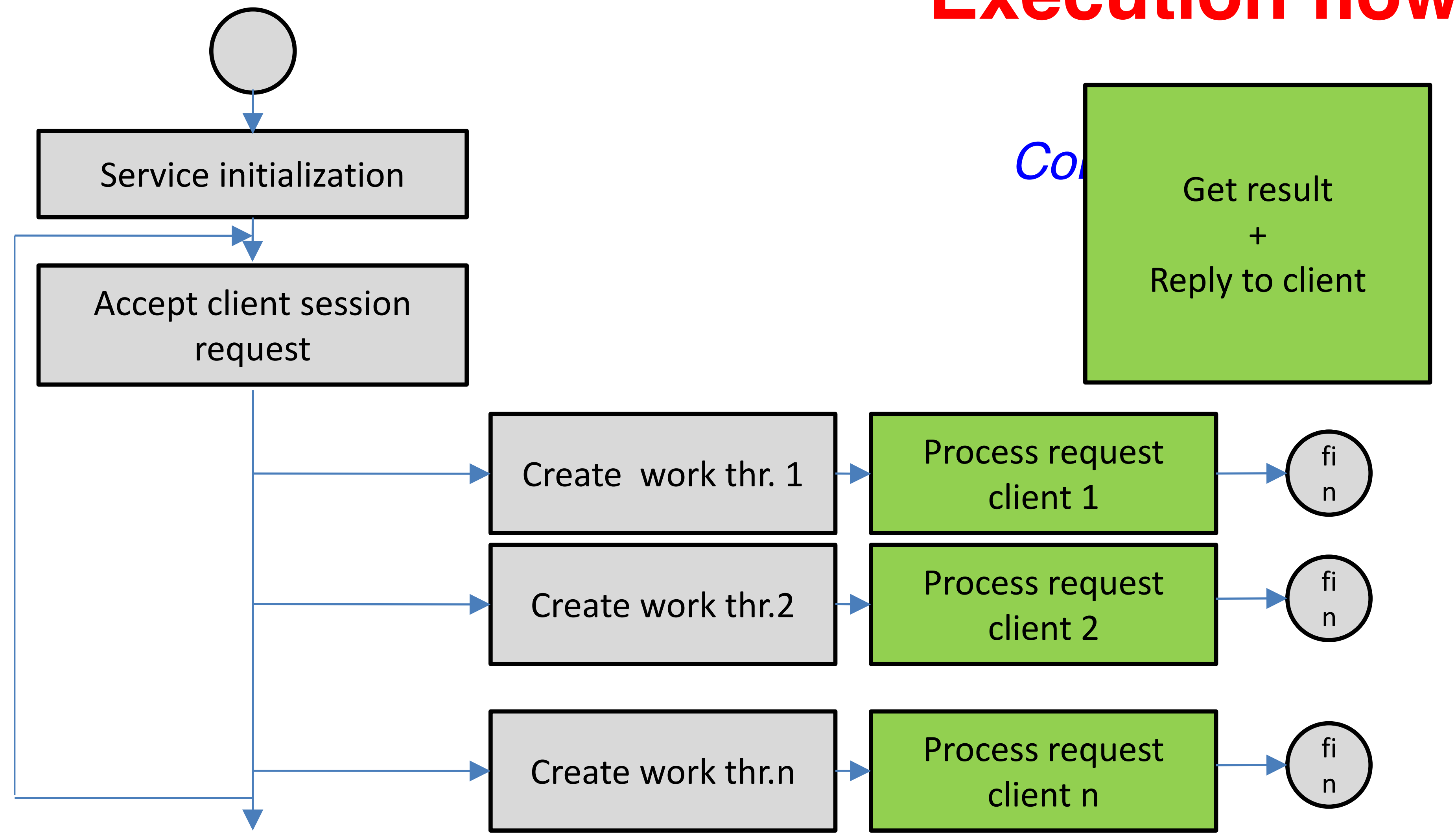
Execution flow

Concurrent server



May use asynchronous inter process communication primitives instead of threads!

Execution flow



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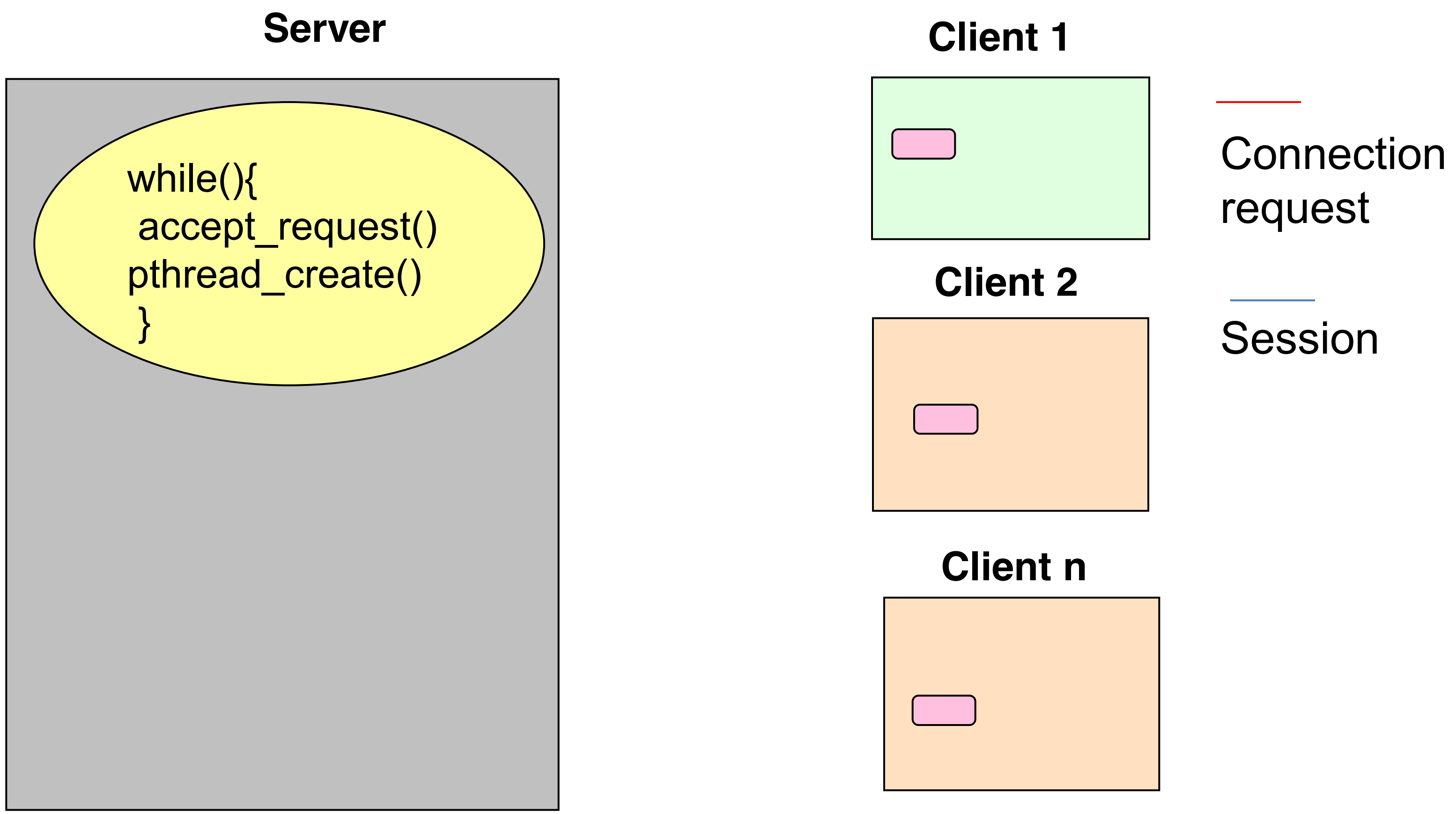
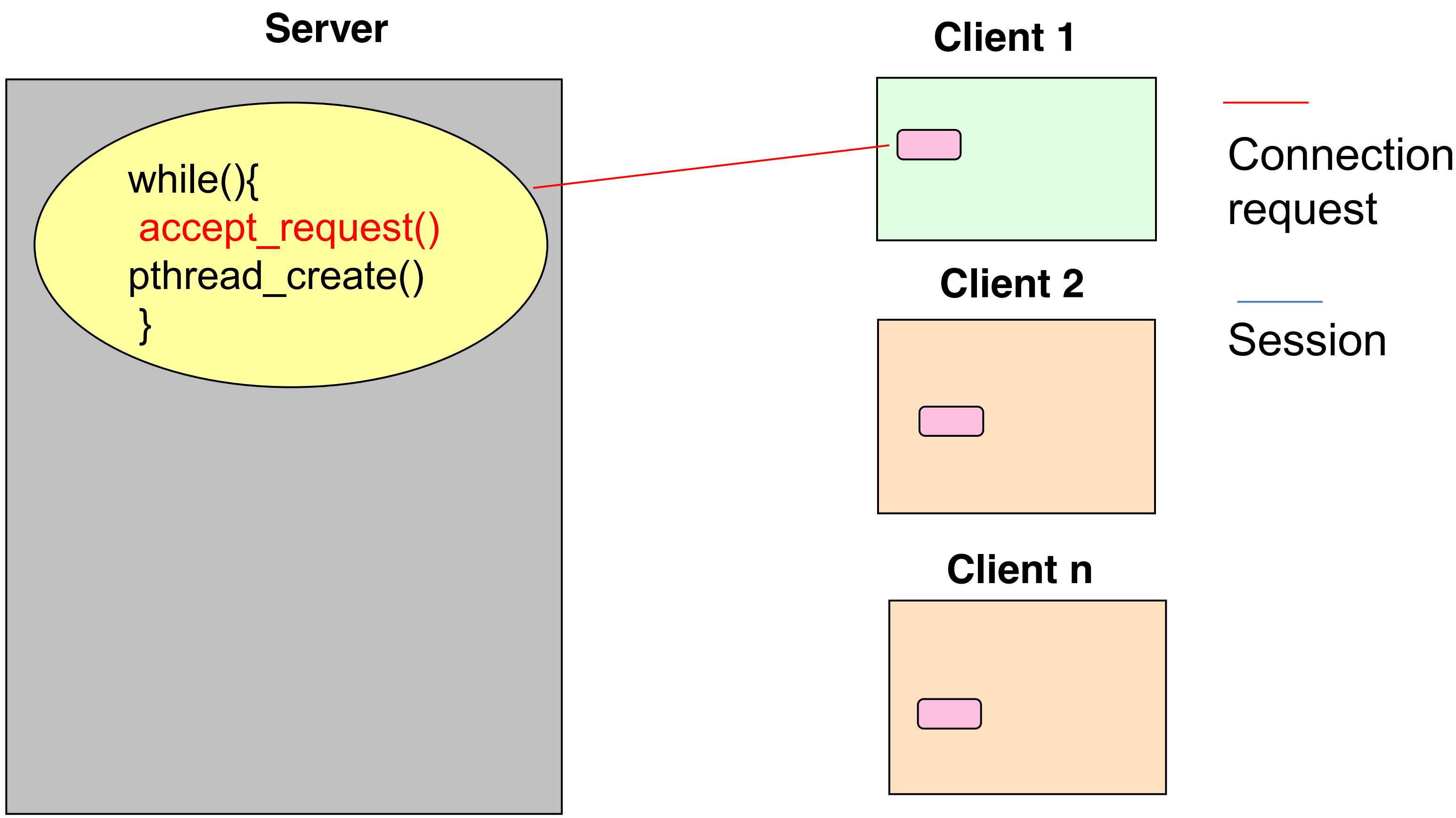
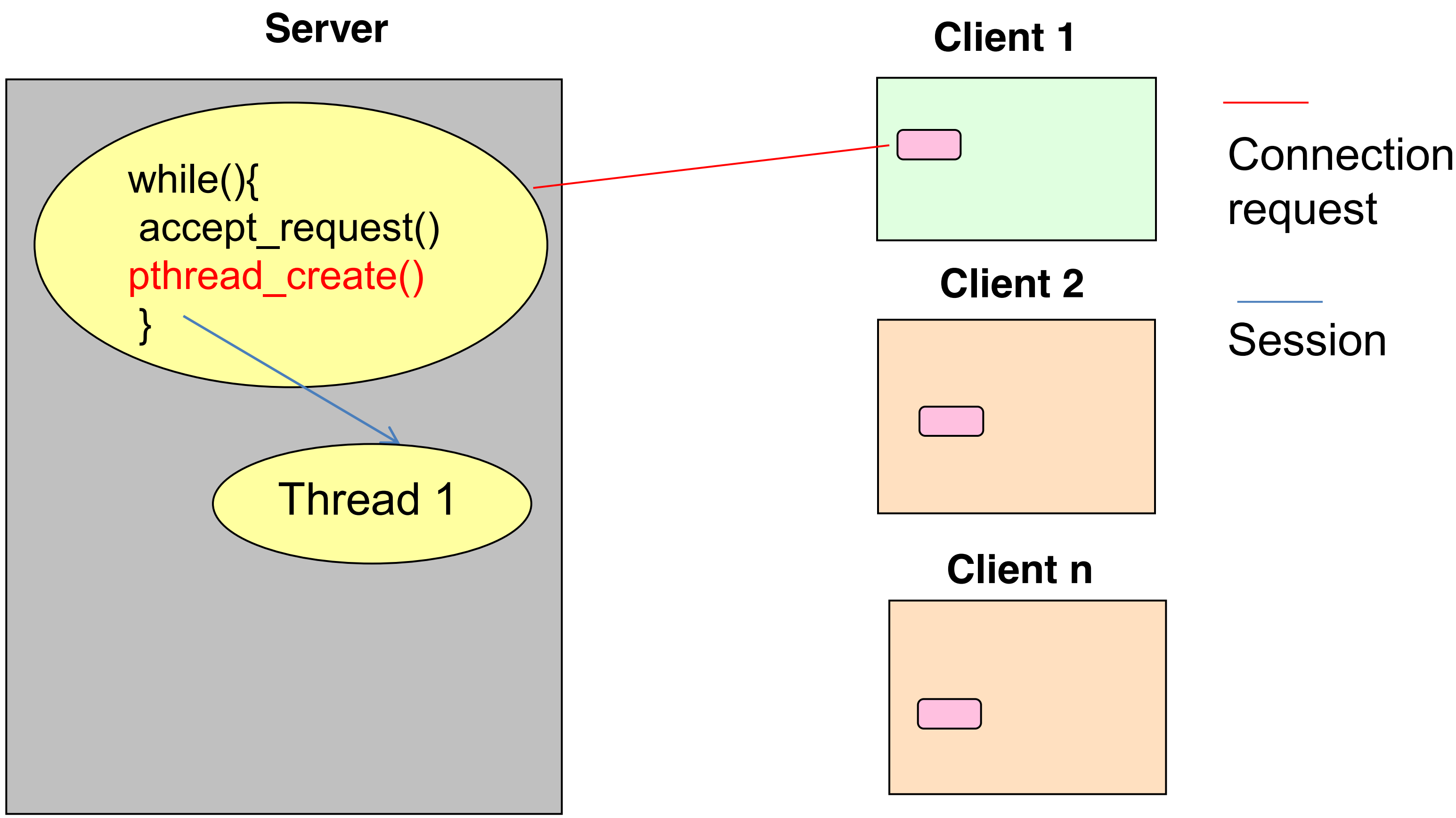
Concurrent Client/Server



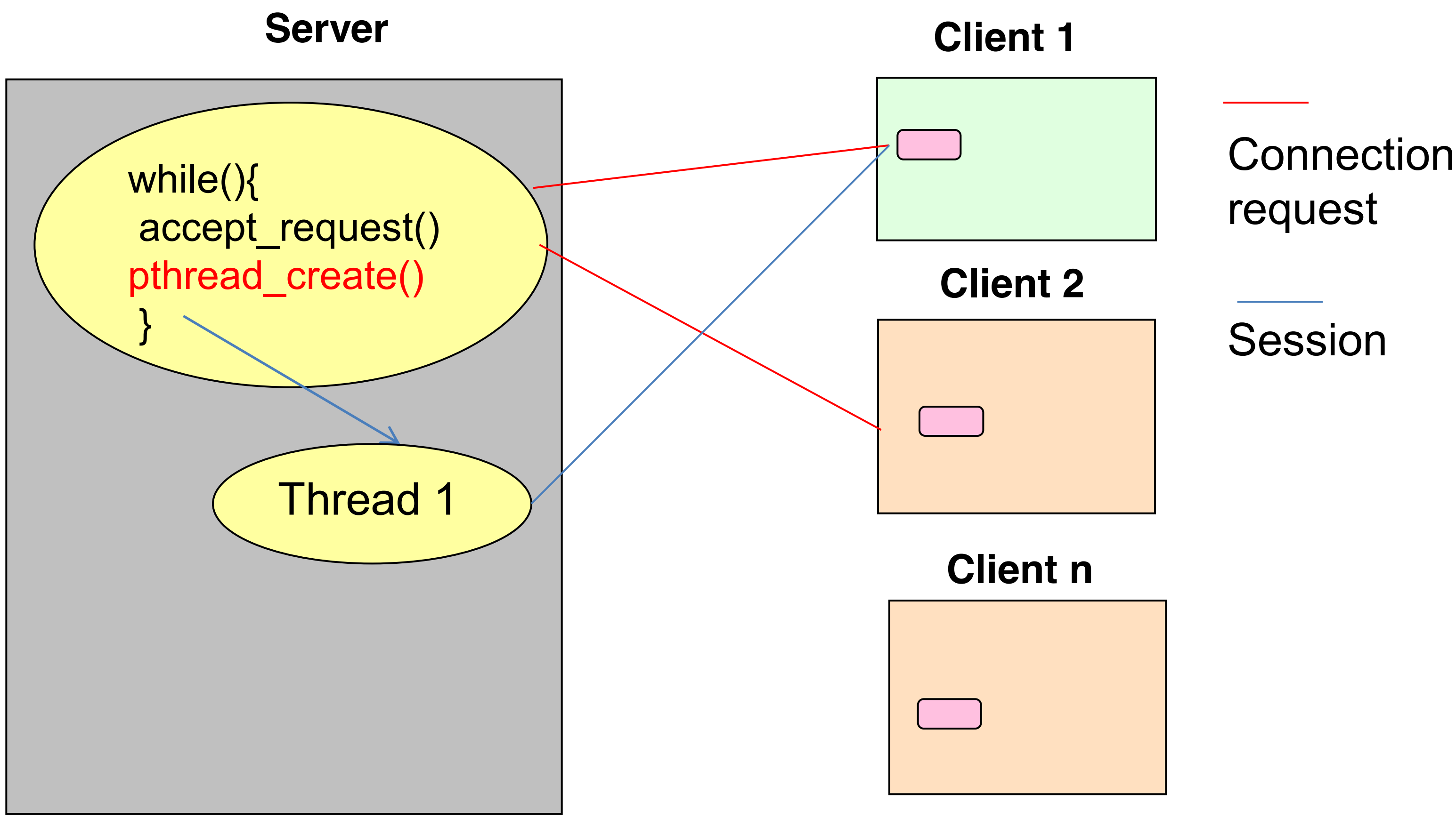
Concurrent Client/Server



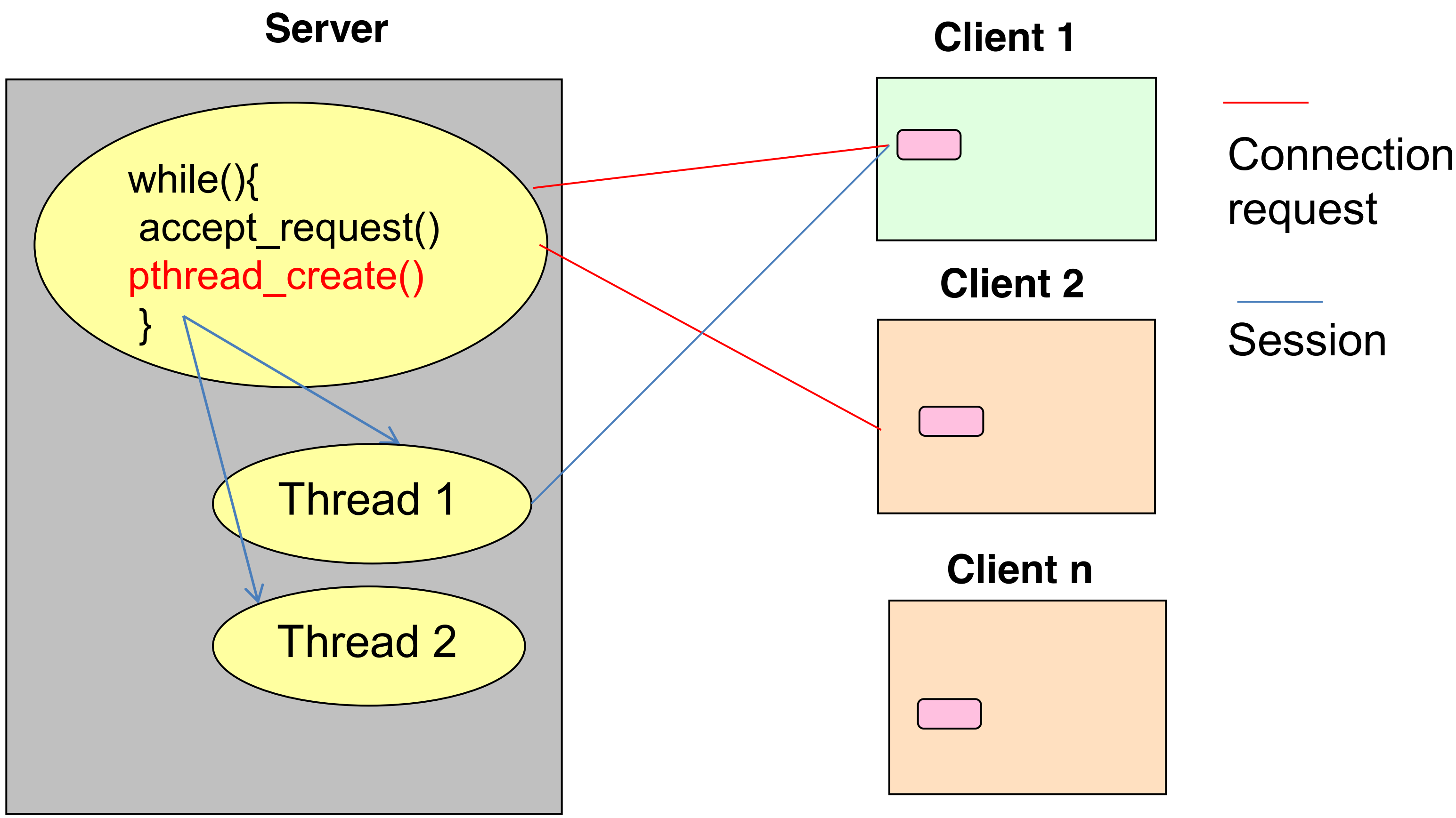
Concurrent Client/Server



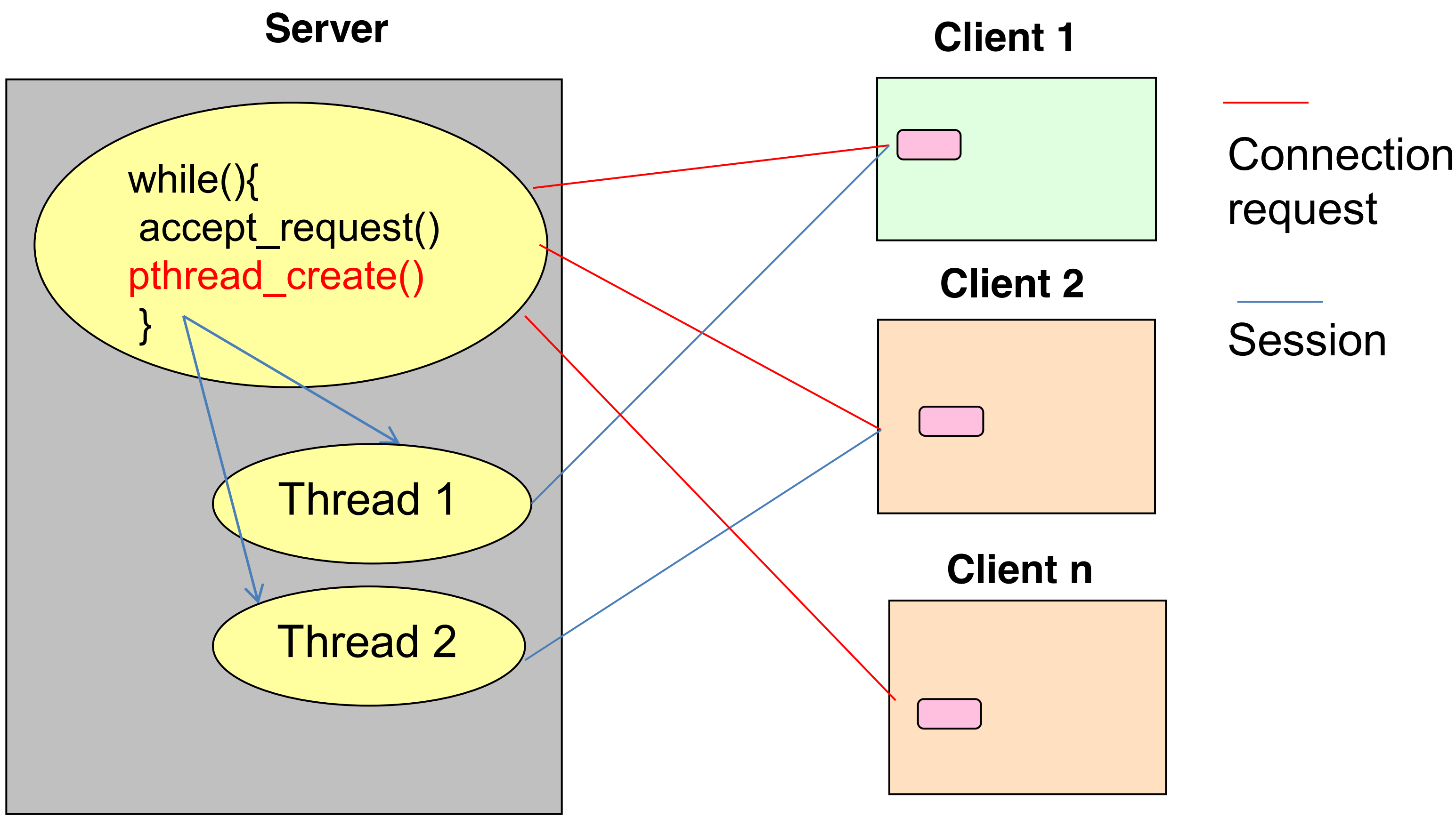
Concurrent Client/Server



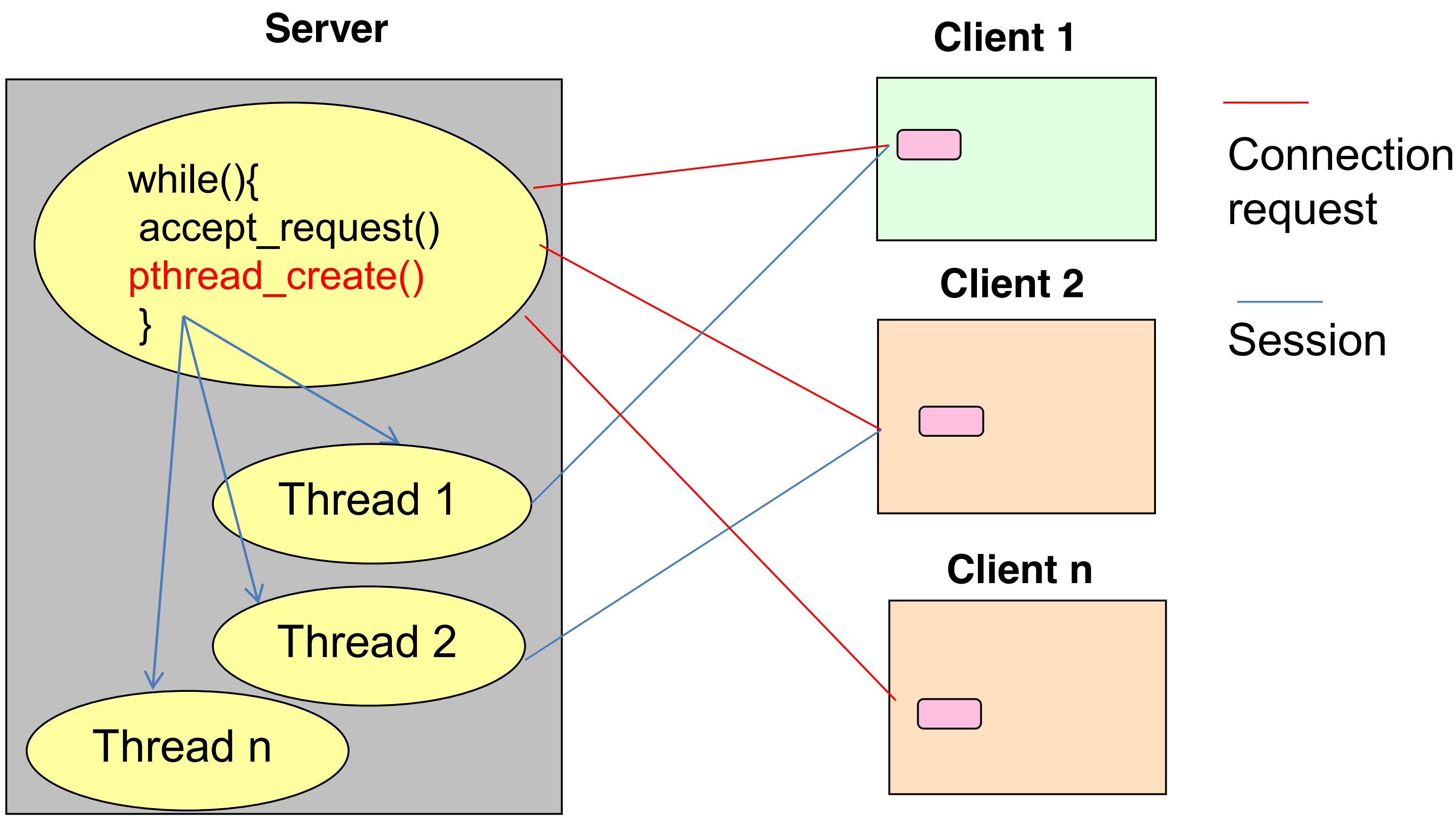
Concurrent Client/Server



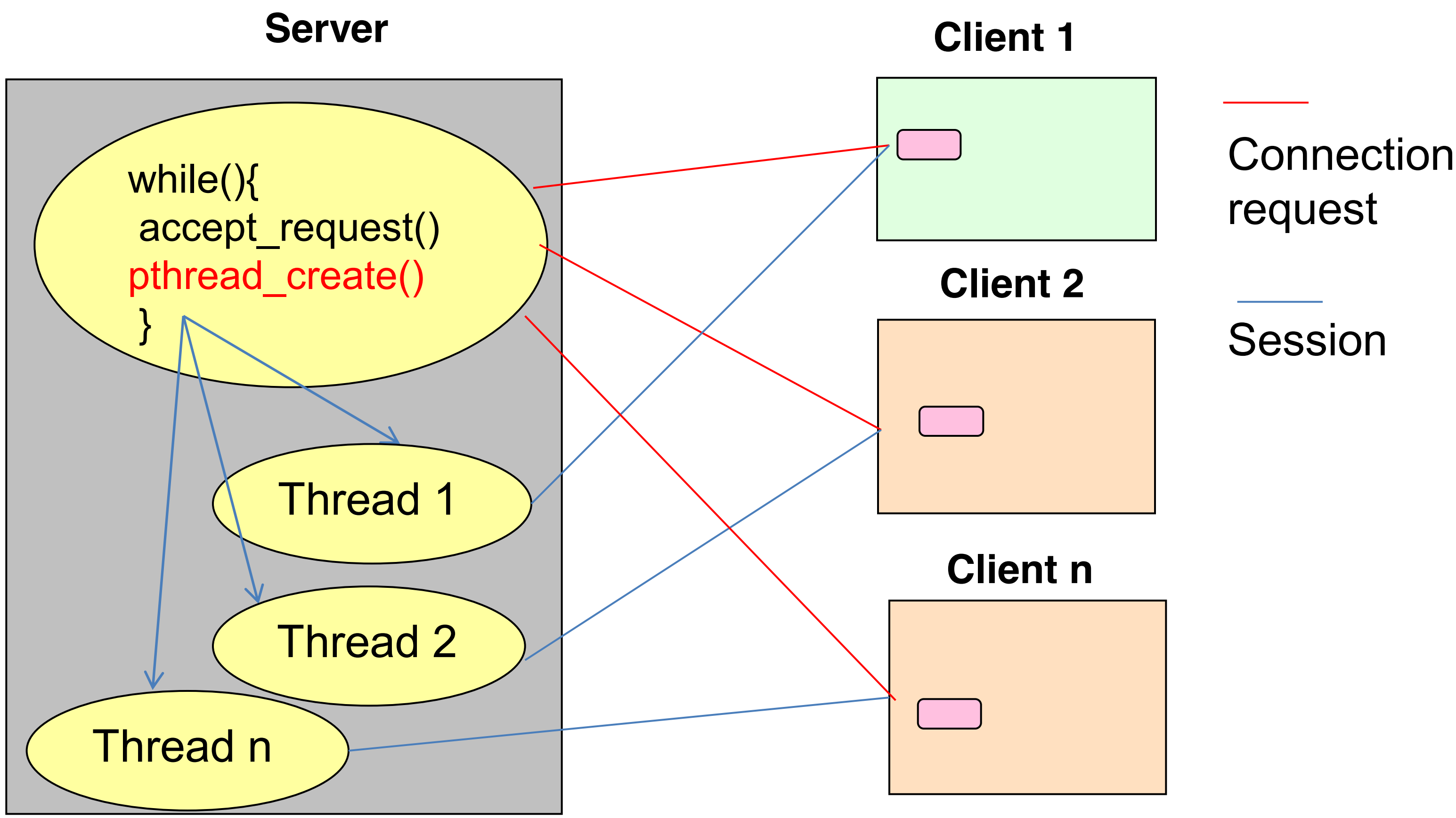
Concurrent Client/Server



Concurrent Client/Server

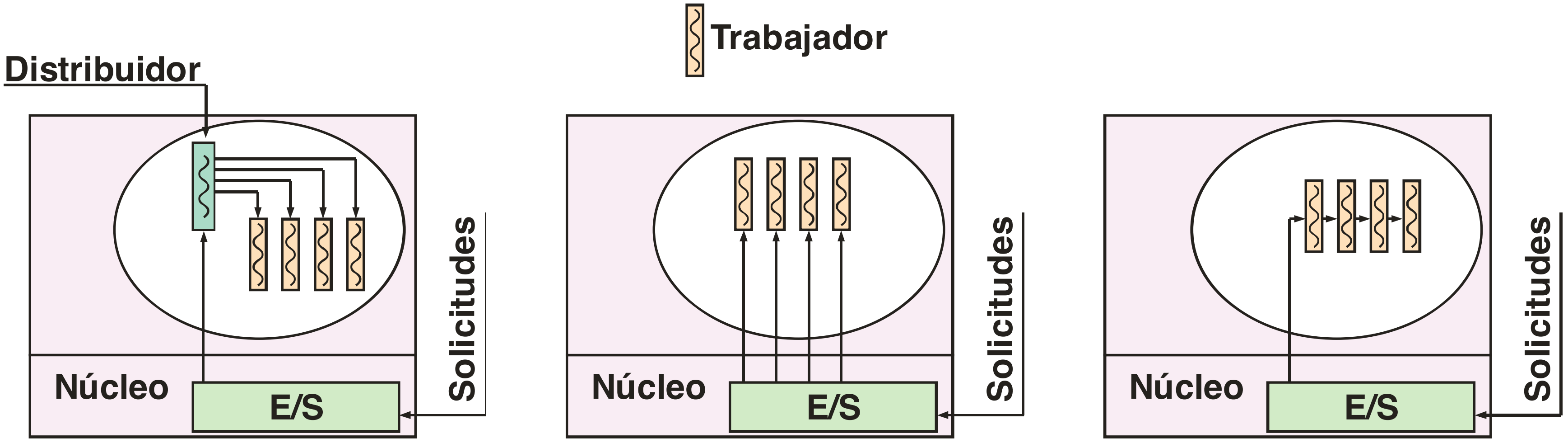


Concurrent Client/Server



Server design using *threads*

- Several alternatives to build parallel servers:
  - A single process which accepts requests and either (1) distributes them to threads from a thread pool or (2) creates a new thread to service the request
  - Set of similar threads which can read requests from a port
  - Pipeline the work and have a specialized thread for each stage



Servers may be…

- Stateless:
  - Every request and reply is independent
  - No state maintained by the server
  - Client may maintain session state and send it as part of the service request to the server
    - Client: “Send me block 1 of file “xxx” from directory “dir”
    - Server: “Here it is”
    - <more of the same>
  - E.g.: HTTP
- Stateful:
  - Maintains state information
  - Each request/reply may depend on previous ones
    - Client: ”Send me file “xxx” from directory “dir”
    - Server: “Here is block 0 of file “xxx”
    - Client: “I have it”
    - Server: “Here is block 1 of file “xxx”
  - E.g.: Telnet

Stateful servers

- Global state:
  - Information common to all clients
  - E.g.: “time of day” server
- Session information
  - Information specific to each client session
  - E.g.: FTP (File Transfer Protocol)

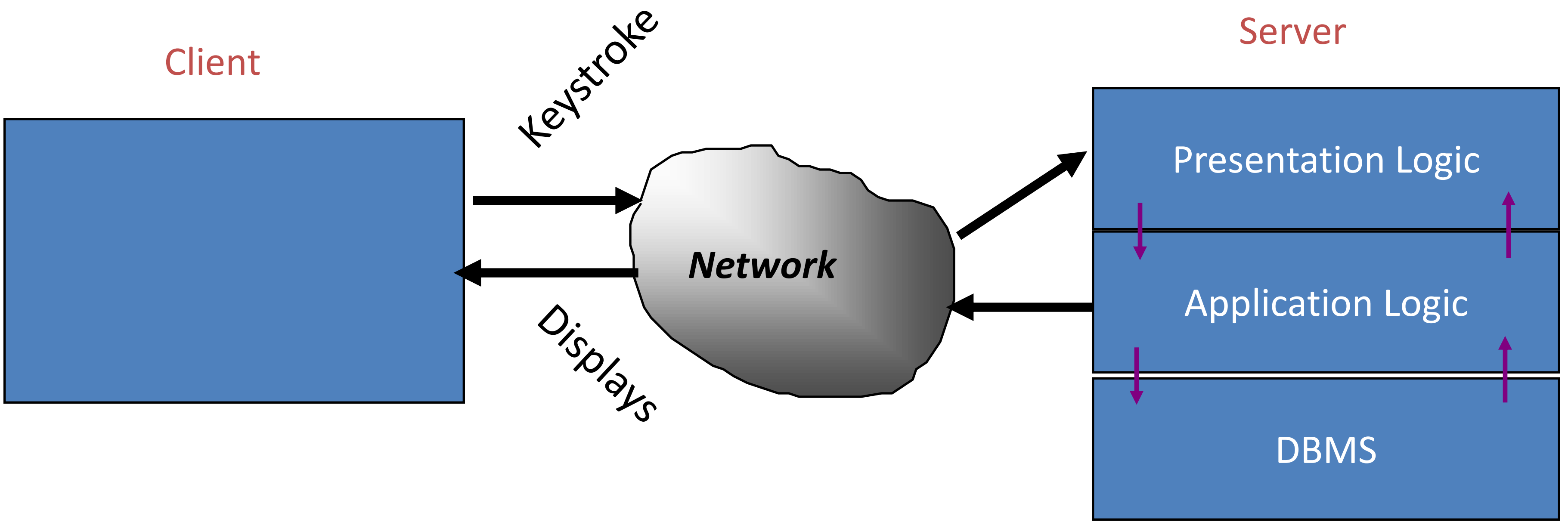
Clients may be…

- Thin: also called lean client or slim client
  - Depends heavily on other computer (e.g. its server) to process most or all of its business logic - which traditional systems like fat clients take on
    - E.g. : the server may need to provide data persistence, process information on client's behalf, etc
  - May be seen as amortizing computing services across several user interfaces
  - Problem: server become single point of failure!
    - Good for checking security thread models
    - Bad if denial of service attack from a client
- Thick: also called fat client or heavy client

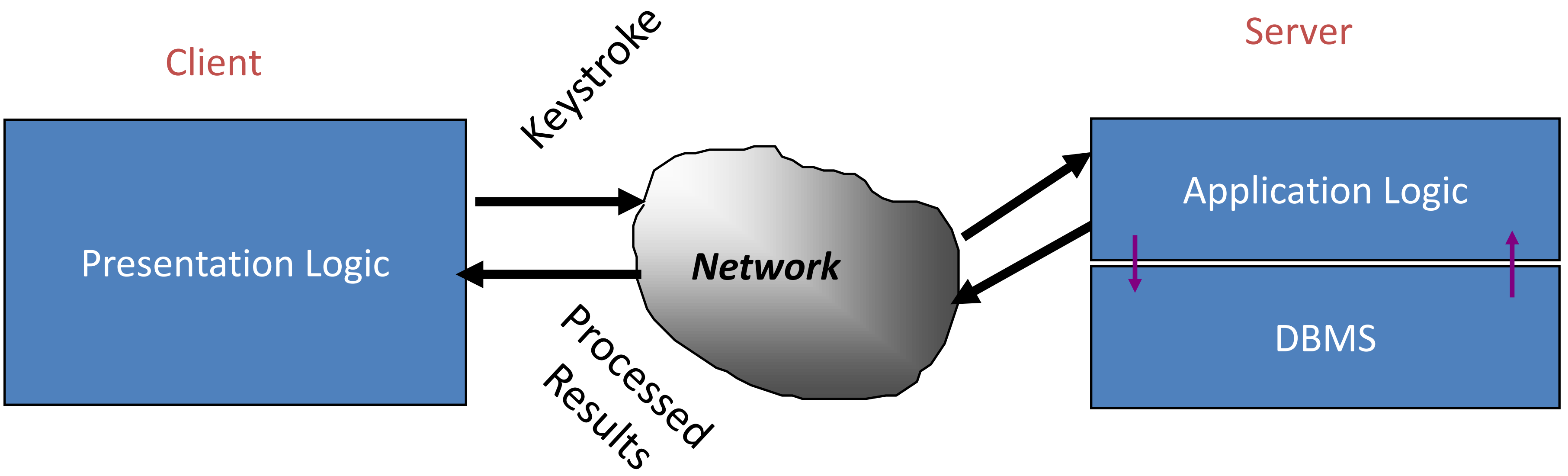
SW architecture

- Usually consists of three layers/tiers:
  - Presentation: user interface issues
  - Application logic: isolates data processing in one location and maximizes reuse, modification in services does not affect presentation
    - Server needs to process client request, compute result and return it to client
    - Client needs to send service request and visualise result
  - Services - we need two types:
    - On server - those processing the request
    - Some IPC mechanism!
    - Must be able to manage data
- May seem similar but different from MVC architecture!
  - View sends updates to controller; controller updates the model, view gets updated directly from model
  - Model = data +domain logic (+persistence, notification)
  - View = query model, render view
  - Controller = init model, wiring up events between controller and V/M

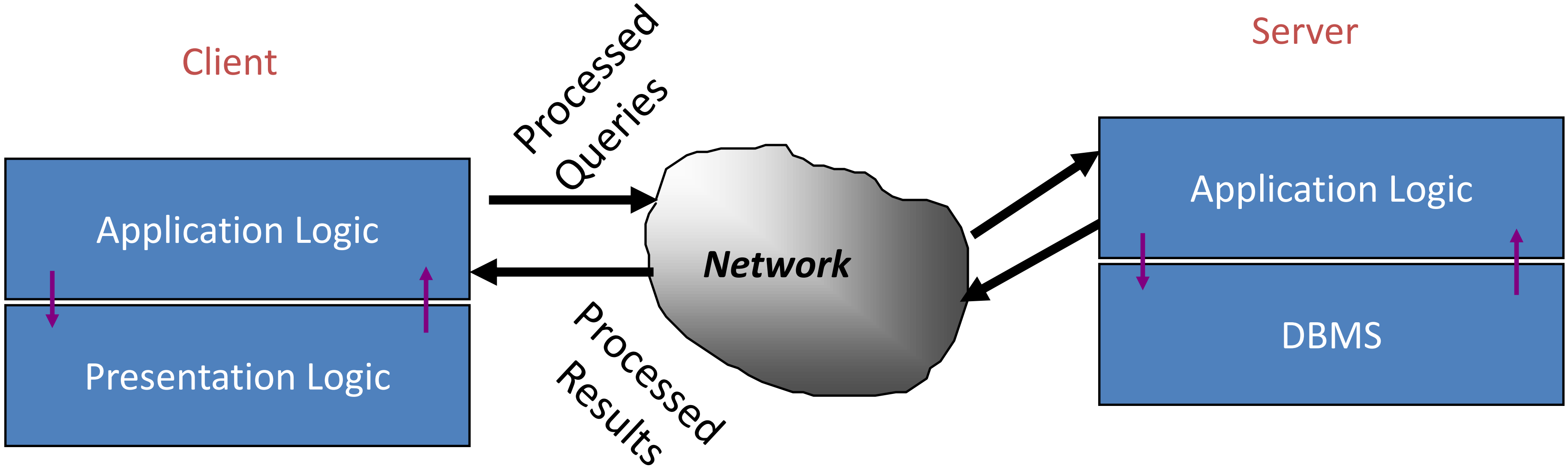
Client (dumb) - Server Model



True Client-Server Model



Distributed Client-Server Model

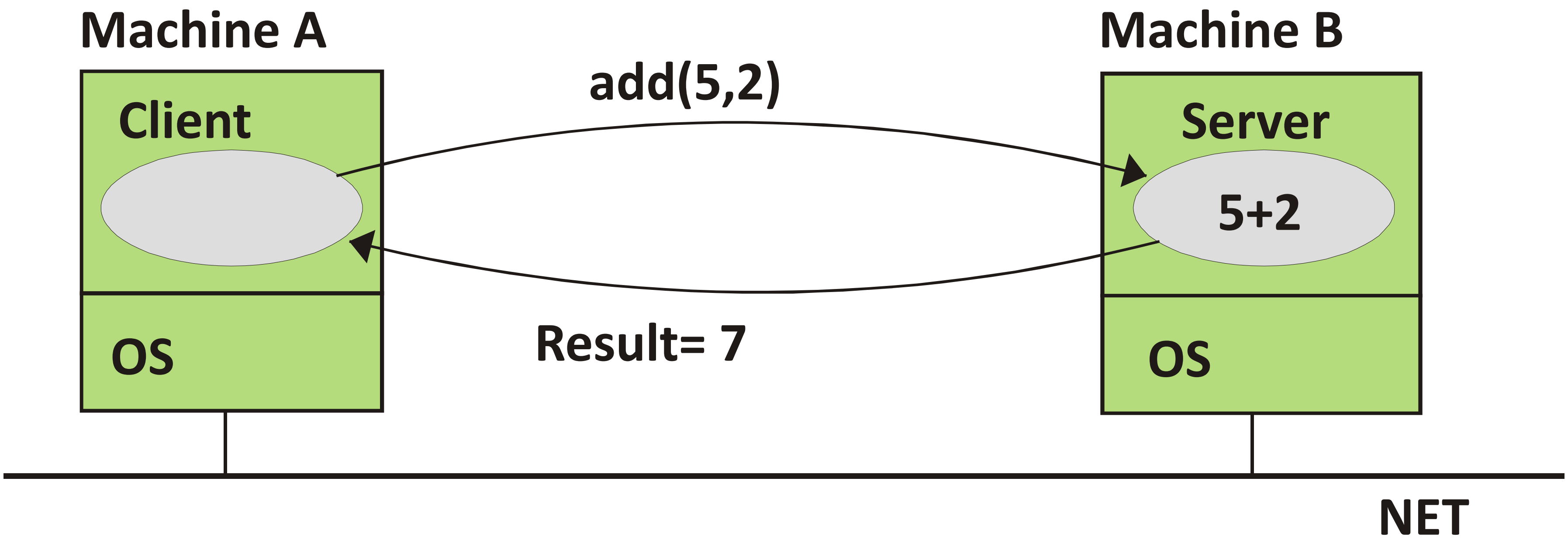


Typical to fat clients
If too complex may want to split into a three-tier

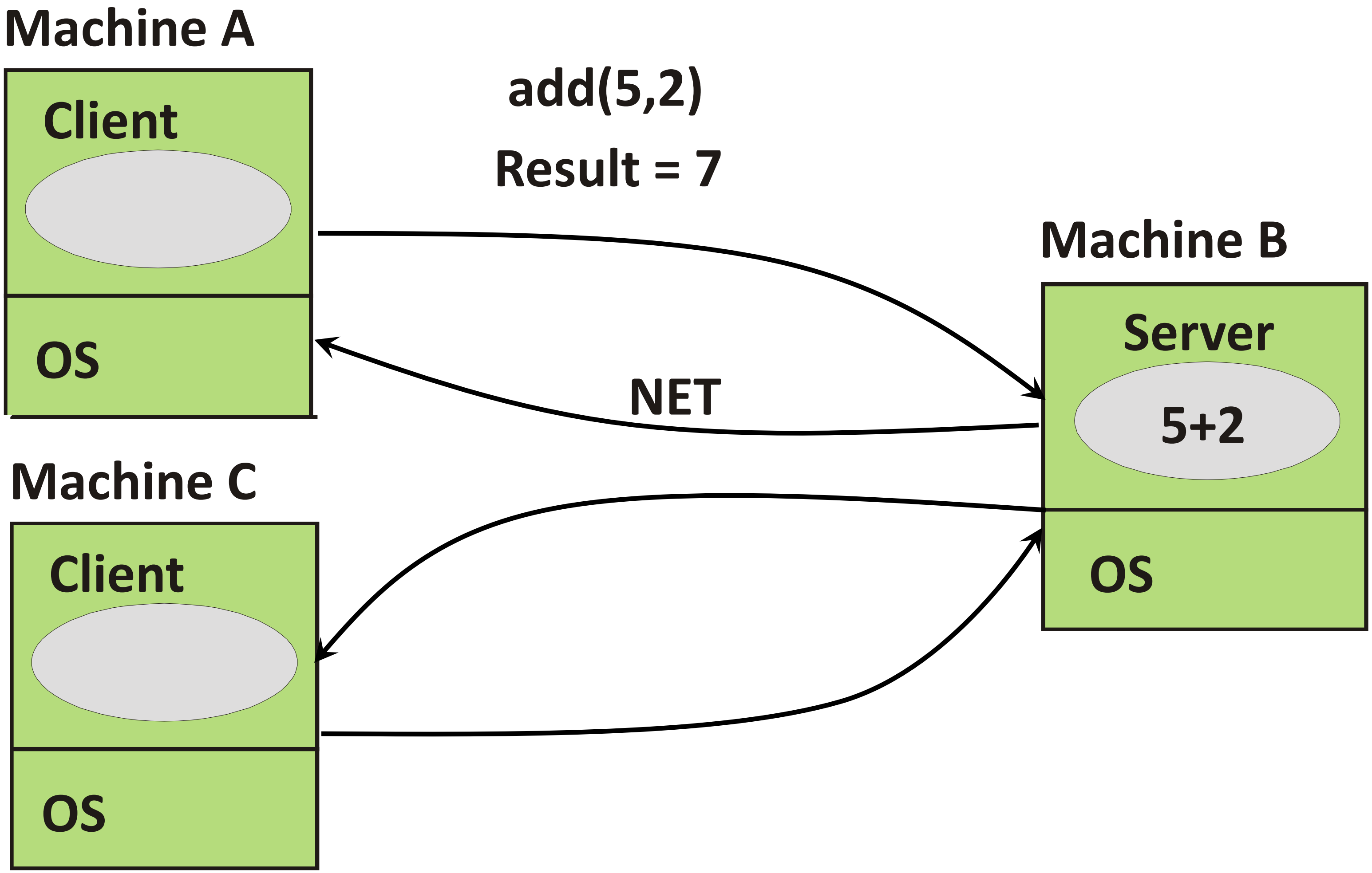
Client/Server applications using message queues

- Distributer thread:
  - Each request results in creating a new work thread which:
    - Processes the request
    - Sends reply to client
  - When client session finishes the thread is destroyed
- Concurrent model:
  - Distributer and work threads execute concurrently

Example: add two numbers



Example: add two numbers

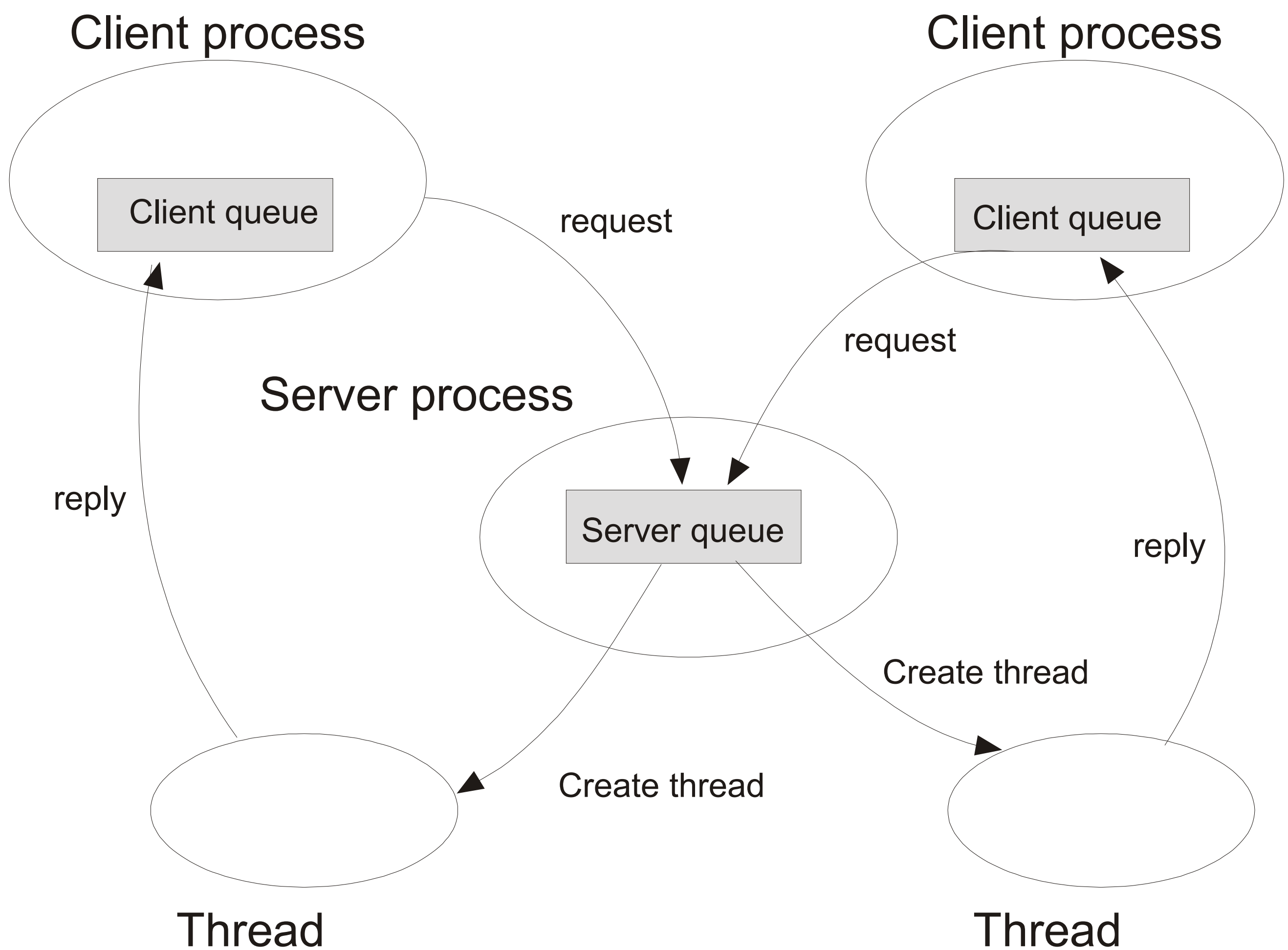


Example: data types

```
#define MAXSIZE        256

struct request  {
   int a;                      /* op. 1 */
   int b;                      /* op. 2 */
   char q_name[MAXSIZE];       /* client queue name - this is
                               where the server sends the reply
                               to */
};
```

The structure of a multithread server



Multithread server with message queues (I)

```
#include "mensaje.h"
#include <mqueue.h>
#include <pthread.h>
#include <stdio.h>

/* mutex and condition variables for the message copy */
pthread_mutex_t mutex_msg;
int msg_not_copied = TRUE;          /* TRUE = 1 */
pthread_cond_t cond_msg;

int main(void)
{
   mqd_t q_server;                  /* server queue */
   struct request msg;              /* message to receive */
   struct mq_attr q_attr;           /* queue atributes */
   pthread_attr_t t_attr;           /* thread atributes */

   q_attr.mq_maxmsg = 20;
   q_attr.mq_msgsize = sizeof(struct request));
```

Multithread server with message queues (II)

```
q_server = mq_open("SERVER", O_CREAT|O_RDONLY, 0700, &attr);
 if (q_server == -1) {
       perror("Can't create server queue");
       return 1;
 }

 pthread_mutex_init(&mutex_msg, NULL);
 pthread_cond_init(&cond_msg, NULL);
 pthread_attr_init(&attr);

 /* thread atributes */
 pthread_attr_setdetachstate(&t_attr, PTHREAD_CREATE_DETACHED);
```

Multithread server with message queues (III)

```
 while (TRUE) {
        mq_receive(q_server, &msg, sizeof(struct request), 0);

        pthread_create(&thid, &attr, process_message, &msg);









   }
}
```

Multithread server with message queues (IV)

```
while (TRUE) {
        mq_receive(q_server, &msg, sizeof(struct request), 0);

        pthread_create(&thid, &attr, process_message, &msg);



    }
}
```

Race condition!!

Multithread server with message queues (V)

```
  while (TRUE) {
        mq_receive(q_server, &msg, sizeof(struct request), 0);

        pthread_create(&thid, &attr, process_message, &msg);

        /* wait for thread to copy message */
        pthread_mutex_lock(&mutex_msg);
        while (message_not_copied)
               pthread_cond_wait(&cond_msg, &mutex_msg);
        message_not_copied = TRUE;
        pthread_mutex_unlock(&mutex_msg);

   }  /* FIN while */
} /* Fin main */
```

Critical section

Multithread server with message queues (VI)

```
void process_message(struct mensaje *msg){
   struct request msg_local;          /* local message */
   struct mqd_t q_client;      /* client queue */
   int result;

   /* thread copies message to local message*/
   pthread_mutex_lock(&mutex_msg);
   memcpy((char *) &msg_local, (char *)&msg, sizeof(struct
        request));

   /* wake up server */
   message_not_copied = FALSE;        /* FALSE = 0 */

   pthread_cond_signal(&cond_msg);

   pthread_mutex_unlock(&mutex_msg);
```

Multithread server with message queues (VII)

```
/* execute client request and prepare reply */
result = msg_local.a + msg_local.b;

/* return result to client by sending it to queue  */
q_client = mq_open(msg_local.name, O_WRONLY);

if (q_client == -1)
     perror("Can't open client queue */
else {
     mq_send(q_client, (char *) &result, sizeof(int), 0);
     mq_close(q_client);
}
pthread_exit(0);
}
```

Client process

```
#include "mensaje.h"
#include <mqueue.h>
void main(void) {
   mqd_t q_server;          /* server message queue */
   mqd_t q_client;          /* client message queue */

   struct request req;
   int res;
   struct mq_attr attr;

   attr.mq_maxmsg = 1;
   attr.mq_msgsize = sizeof(int);
   q_client = mq_open("CLIENT_ONE", O_CREAT|O_RDONLY, 0700, &attr);

   q_server = mq_open("ADD_SERVER", O_WRONLY);

   /* fill in request */
   req.a = 5;     req.b = 2;   strcpy(req.q_name, "CLIENT_ONE");

   mq_send(q_server, &req, sizeof(struct request), 0);
   mq_receive(q_client, &res, sizeof(int), 0);

   mq_close(q_server);
   mq_close(q_client);
   mq_unlink("CLIENT_ONE");
}
```