Synchronization#3: Message Based

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Message-based Synchronization

- Synchronization model
  - Asynchronous
  - Synchronous
  - Remote invocation
- Addressing (name space)
  - direct communication
  - mail-box communication
- Message structure
  - arbitrary
  - restricted to 'basic' types
  - restricted to un-typed communications

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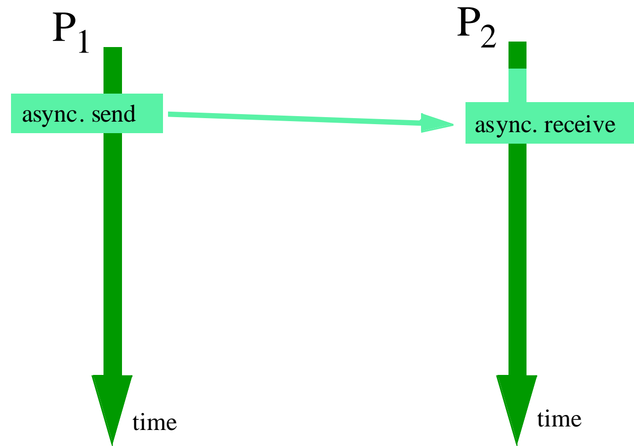
Asynchronous Messages



- If there is a listener:
  - send the message directly

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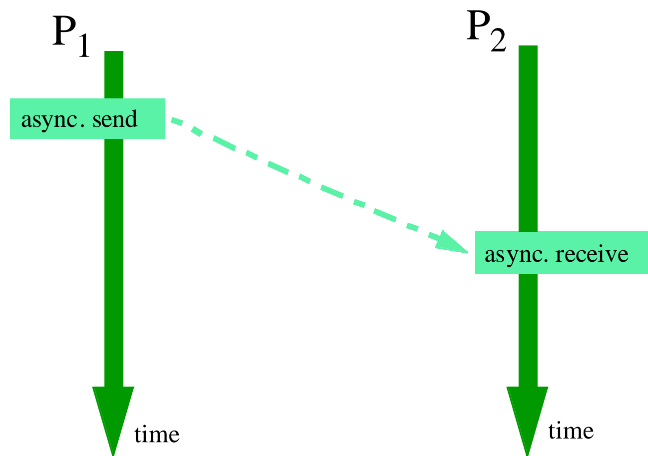
Asynchronous Messages



- If the receiver becomes available at a later stage:
  - the message needs to be buffered

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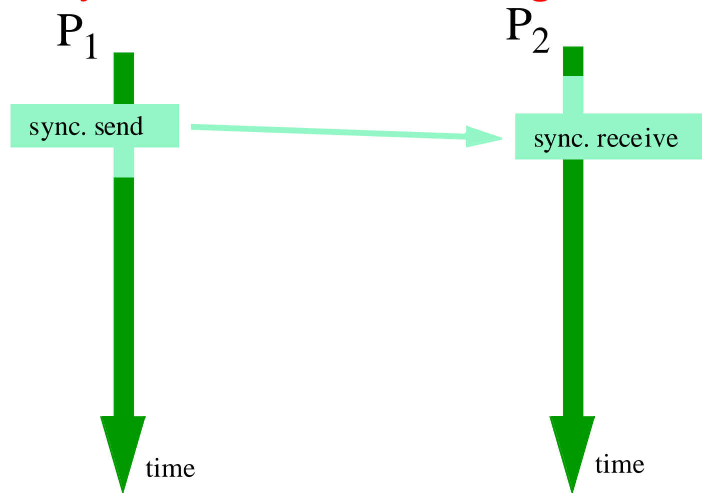
Synchronous Messages



- Delay the receiver:
  - until the message becomes available

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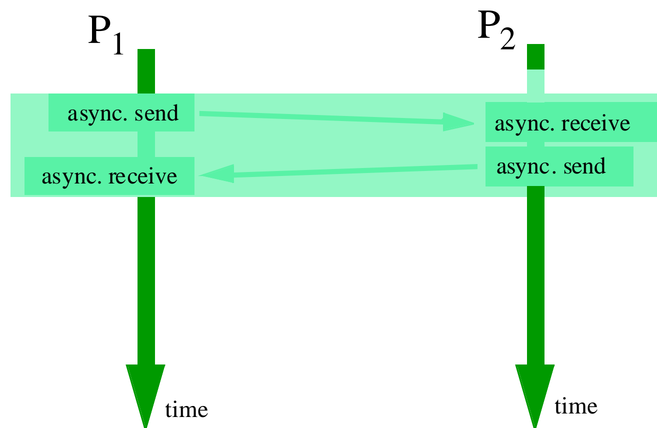
Synchronous Messages



- Delay the receiver:
  - until the message becomes available
- Simulated by asynchronous messages:
  - two asynchronous messages required

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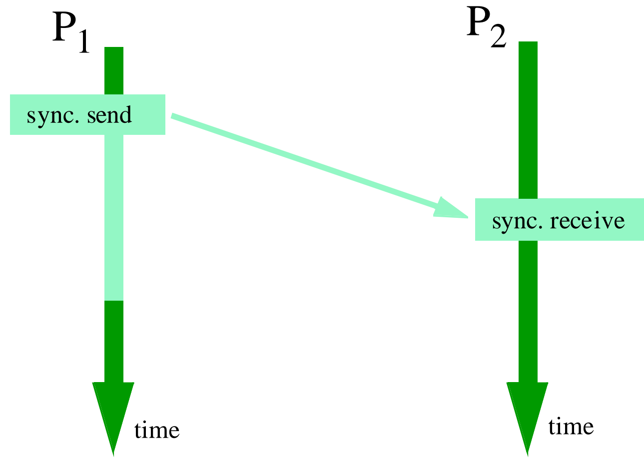
Synchronous Messages



- Delay the sender until:
  - a receiver is available
  - a receiver got the message

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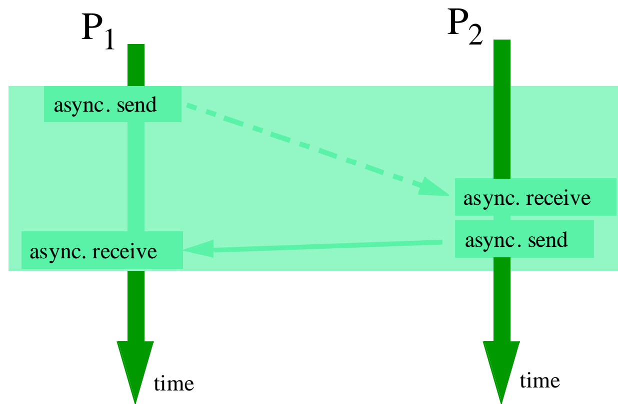
Synchronous Messages



- Delay the sender until:
  - a receiver is available
  - a receiver got the message
- Simulated by asynchronous messages and receiver becomes available at a later stage:
  - message needs to be buffered

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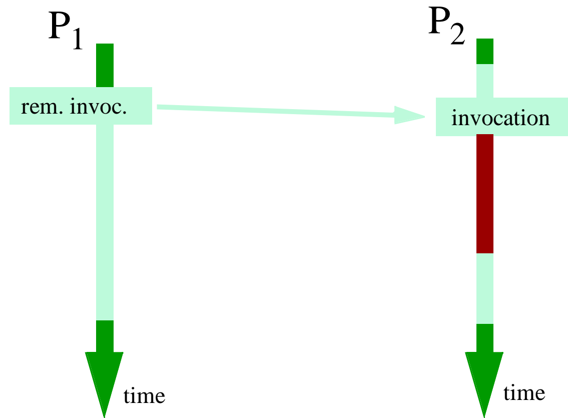
Remote Invocation



- Delay the receiver, until:
  - an invocation is available
  - a receiver executed an addressed routine

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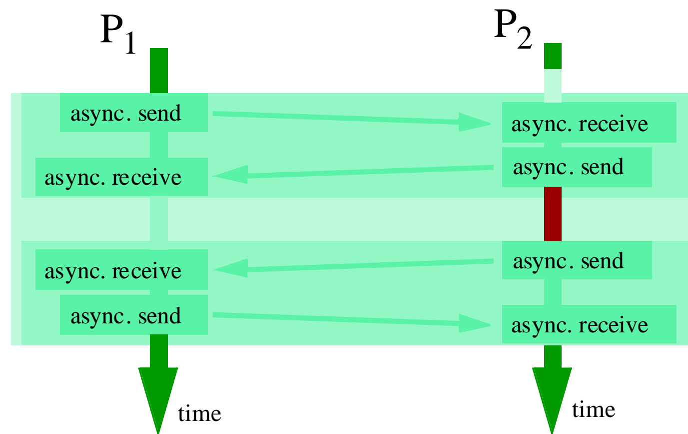
Remote Invocation



- Delay the receiver, until:
  - an invocation is available
  - a receiver executed an addressed routine
- Simulated by asynchronous messages:
  - four messages are required

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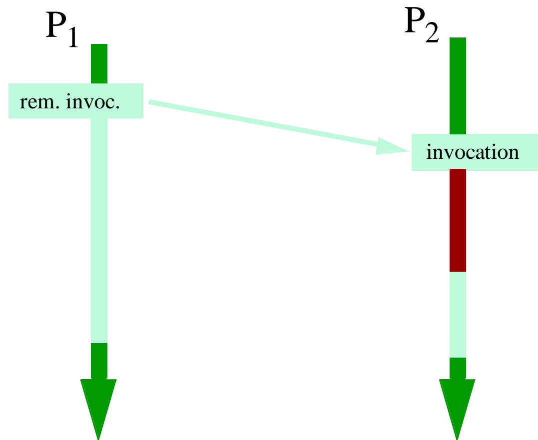
Remote Invocation



- Delay the sender, until:
  - a receiver becomes available
  - a receiver got the message
  - a receiver executed an addressed routine

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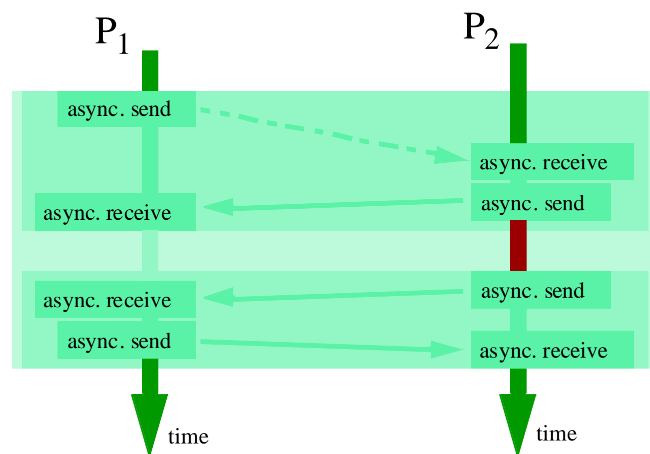
Remote invocation



- Delay the sender, until:
  - a receiver becomes available
  - a receiver got the message
  - a receiver executed an addressed routine
- Simulated by asynchronous messages:
  - four messages are required
  - message buffering required

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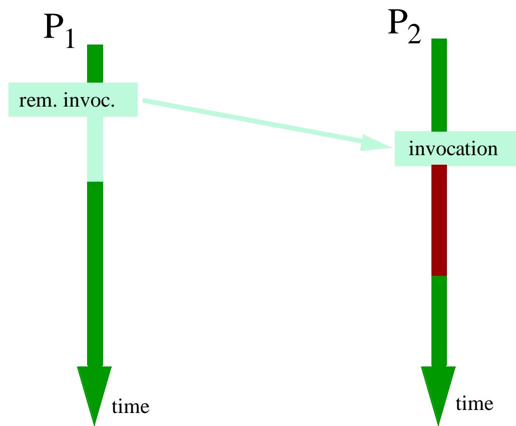
Asynchronous Remote Invocation



- Delay the sender, until:
  - a receiver becomes available
  - a receiver got the message

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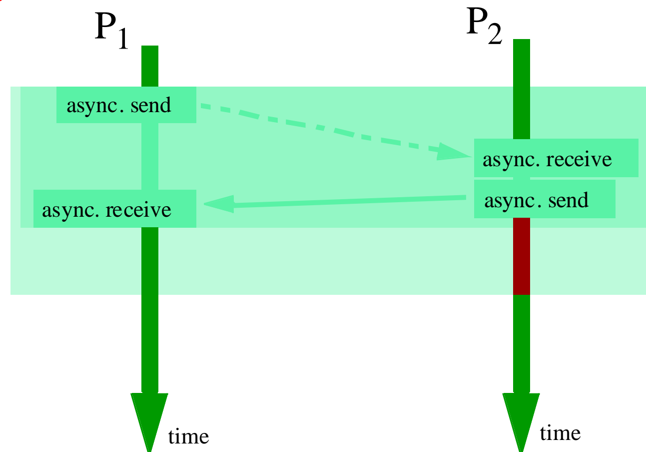
Asynchronous Remote Invocation



- Delay the sender, until:
  - a receiver becomes available
  - a receiver got the message
- Simulated by asynchronous messages:
  - two messages are required

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Synchronous vs. Asynchronous

- **Purpose**
  - **synchronization**: synchronous messages / remote invocations
  - **in-time delivery**: asynchronous messages / asynchronous remote invocations
- ‘Real’ synchronous message passing in distributed systems requires hardware support.
- Asynchronous message passing requires the usage of (infinite?) buffers.
- **Emulation**
  - Synchronous communications are emulated by a combination of asynchronous messages in some systems.
  - Asynchronous communications can be emulated in synchronized message passing systems by introducing ‘buffer-tasks’ (de-coupling sender and receiver as well as allowing for broadcasts).

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Addressing (name space)

- Direct vs. indirect:

```
send     <message> to   <process-name>
wait for <message> from <process-name>
send     <message> to   <mailbox>
wait for <message> from <mailbox>
```

- Asymmetrical addressing:

```
send     <message> to …
wait for <message>
```

  - Client-server paradigm

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Addressing (name space)

Communication medium:

Connections	***Functionality***
one-to-one	buffer, queue, synchronization
one-to-many	multicast
one-to-all	broadcast
many-to-one	local server, synchronization
all-to-one	general server, synchronization
all-to-one	general network- or bus-system

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Message structure

- Machine dependent representations need to be taken care of in a distributed environment.
- Communication system is often outside the typed language environment.
  - Most communication systems are handling streams (packets) of a basic element type only.
- Conversion routines for data-structures other then the basic element type are supplied …
  - manually (POSIX, 'C/C++', Java)
  - semi-automatic (CORBA)
  - automatic and are typed-persistent (Ada95, CHILL, Occam2)

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Message Structure (Ada95)

```
package Ada.Streams is
   pragma Pure (Streams);
   type Root_Stream_Type is abstract tagged limited private;
   type Stream_Element is mod implementation-defined;
   type Stream_Element_Offset is range implementation-defined;
   subtype Stream_Element_Count is
      Stream_Element_Offset range 0..Stream_Element_Offset'Last;
   type Stream_Element_Array is
      array (Stream_Element_Offset range <>) of Stream_Element;
   procedure Read  (…) is abstract;
   procedure Write (…) is abstract;
private
   … -- not specified by the language
end Ada.Streams;
```

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Message Structure (Ada95)

Reading and writing values of any type to a stream:

```
procedure S'Write(Stream : access
      Ada.Streams.Root_Stream_Type'Class; Item : in  T);
procedure S'Class'Write(Stream : access
      Ada.Streams.Root_Stream_Type'Class; Item : in  T'Class);
procedure S'Read(Stream : access
      Ada.Streams.Root_Stream_Type'Class; Item : out T);
procedure S'Class'Read(Stream : access
      Ada.Streams.Root_Stream_Type'Class; Item : out T'Class)
```

Reading and writing values, bounds and discriminants of any type to a stream:

```
procedure S'Output(Stream : access
      Ada.Streams.Root_Stream_Type'Class; Item : in  T);
function  S'Input(Stream : access
      Ada.Streams.Root_Stream_Type'Class) return T;
```

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Practical Message-Passing Systems

POSIX:	"message queues": – **ordered indirect [asymmetrical | symmetrical] asynchronous byte-level many-to-many message passing**
CHILL	"buffers", "signals": – **ordered indirect [asymmetrical | symmetrical] [synchronous | asynchronous] typed [many-to-many | many-to-one] message passing**
Occam2	"channels": – **indirect symmetrical synchronous fully-typed one-to-one message passing**
Ada95:	"(extended) rendezvous": – **ordered direct asymmetrical [synchronous | asynchronous] fully-typed many-to-one remote invocation**
Java:	no communication via messages available

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Practical Message-Passing Systems

	Ordered	**Symmetrical**	**Assymetrical**	**Synchronous**	**Asynchronous**	**Direct**	**Indirect**	**Contents**	**One-to-one**	**Many-to-one**	**Many-to-many**	**Method**
POSIX	*	*	*		*		*	bytes			*	message passing
CHILL	*	*	*	*	*		*	typed		*	*	message passing
Occam2		*		*			*	fully typed	*			message passing
Ada95	*		*	*	*	*		fully typed		*		remote invocation
Java	no communication via messages available											

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Practical Message-Passing Systems: for strict synchronization purposes

	Ordered	Symmetrical	Assymetrical	Synchronous	Asynchronous	Direct	Indirect	Contents	One-to-one	Many-to-one	Many-to-many	Method
~~POSIX~~	*	*	*		*		*	bytes			*	message passing
CHILL	*	*	*	*	*		*	typed		*	*	message passing
Occam2		*		*			*	fully typed	*			message passing
Ada95	*		*	*	*	*		fully typed		*		remote invocation
~~Java~~	no communication via messages available											

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Message-Based Synchronization in Occam2

- Communication is ensured by means of a ‘channel’, which:
  - can be used by one writer and one reader process only
  - is synchronous:

```
CHAN OF INT SensorChannel:
PAR
   INT reading:
   SEQ i = 0 FOR 1000
      SEQ
         -- generate reading
         SensorChannel ! reading
   INT data:
   SEQ i = 0 FOR 1000
      SEQ
         SensorChannel ? data
         -- employ data
```

tasks are synchronized at these points

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Message-Based Synchronization in CHILL

- **CHILL** is the 'CCITT High Level Language',
  - where **CCITT** is the Comité Consultatif International Télégraphique et Téléphonique.
- The CHILL language development was started in 1973 and standardized in 1979.
  - strong support for concurrency, synchronization, and communication (monitors, buffered message passing, synchronous channels)

```
dcl SensorBuffer buffer (32) int;
…
send SensorBuffer (reading);  |  receive case
               --- asynchronous --->(SensorBuffer in data) :
…
                              |  esac;
signal SensorChannel = (int) to consumertype;
…
send SensorChannel (reading)  |  receive case
   to consumer <--- synchronous ---> (SensorChannel in data):
…
                              |  esac;
```

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Message-based synchronization in Ada95

- Ada95 supports remote invocations ((extended) rendezvous) in form of:
  - **entry points** in tasks
  - **full set of parameter profiles** supported
- If the local and the remote task are on different architectures, or if an intermediate communication system is employed:
  - parameters incl. bounds and discriminants are 'tunnelled' through byte-stream-formats.
- Synchronization:
  - both tasks are synchronized at the beginning of the remote invocation (+ '**rendezvous**')
  - the calling task if blocked until the remote routine is completed (+ '**extended rendezvous**')

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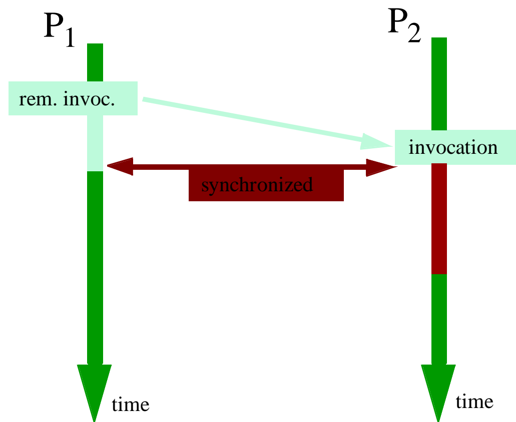
Remote invocation: Rendezvous



- Delay the sender, until:
  - a receiver becomes available
  - a receiver got the message
  - a receiver started an addressed routine

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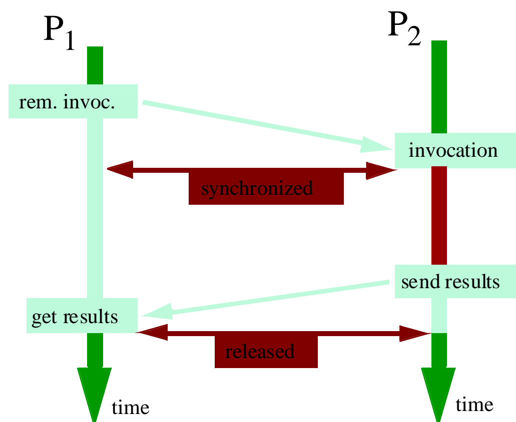
Remote Invocation: Extended Rendezvous



- Delay the sender, until:
  - a receiver becomes available
  - a receiver got the message
  - a receiver executed an addressed routine
  - a receiver passed the results

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Ada95: Rendezvous

```
…                                                    …
<entry_name> [(index)] <parameters>                  …
… -- waiting for synchronization                     …
… --                                                 …
… --                                                 …
… --     <------- synchronized ------->              accept <entry_name> [(index)]
…                                                           <parameter_profile>;
…                                                    …
…                                                    …
…                                                    …
…                                                    …
                                                     …
```

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Ada95: Rendezvous

```
…                                        …
…                                        accept <entry_name> [(index)]
…                                               <parameter_profile>;
…                                        … -- waiting for synchronization
…                                        … --
<entry_name> [(index)] <parameters>  <-  … --  synchronized  ->
…                                        …
…                                        …
…                                        …
…                                        …
```

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Ada95: Extended Rendezvous

```
…                                                  …
<entry_name> [(index)] <parameters>                …
… -- waiting for synchronization                   …
… --                                               …
… --                                               …
… --        <---- [synchronized] ---->             accept <entry_name> [(index)]
     … --                                                  <parameter_profile> do
     … -- blocked                                    … --
     … --                                            … -- remote invocation
     … --                                            … --
…           <---- [return result] ----             end <entry_name>;
                                                   …
```

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Ada95: Extended Rendezvous

```
…                                                  …
…                                                  accept <entry_name> [(index)]
…                                                          <parameter_profile> do
…                                                  … -- waiting for synchronization
…                                                  … --
<entry_name> [(index)] <parameters>  <---- [synchronized] ---->
     … --                                            … --
     … -- blocked                                    … --
     … --                                            … -- remote invocation
     … --                                            … --
…           <---- [return result] ----             end <entry_name>;
                                                   …
```

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Task Entries

- In contrast to protected-object-entries, task-entries *can* call other blocking operations.
- Accept statements can be nested (but need to be different).
  - helpful e.g. to synchronize more than two tasks.
- Accept statements can have a dedicated exception handler (like any other code-block).
- Exceptions, which are not handled during the rendezvous phase are propagated to *all* involved tasks.
- Parameters cannot be direct 'access' parameters, but can be access-types.
- 'count on task-entries is defined, but is only accessible from inside the tasks owning the entry.
- **Entry families** (arrays of entries) are supported.
- **Private entries** (accessible for internal tasks) are supported.

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Synchronization

- **Shared memory based synchronization**
  - Flags, condition variables, semaphores, …
    … conditional critical regions, monitors, protected objects.
  - Guard evaluation times, nested monitor calls, deadlocks, …
    … simultaneous reading, queue management.
  - Synchronization and object orientation, blocking operations and re-queuing.
- **Message based synchronization**
  - Synchronization models
  - Addressing modes
  - Message structures
  - Examples

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