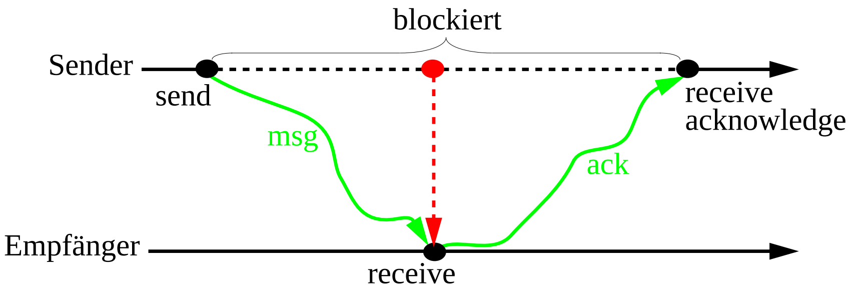
Synchrone Kommunikation

- Synchrone Kommunikation: syn chron
  "send" und "receive" geschehen virtuell gleichzeitig



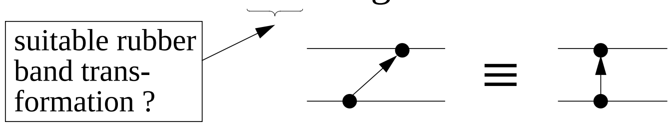
- Sender ist blockiert, bis er vom Empfang seiner Nachricht erfährt
  - Sendezeitpunkt ist innerhalb des Blockadeintervalls beliebig verschiebbar
  - als wäre der Sender vor und nach dem virtuellen Sendezeitpunkt "idle"

- Konsequenz:
  Man darf so tun, als wären Nachrichten nie unterwegs!
  - "blitzschnelle" Nachrichten
  - vereinfacht viele Argumentationen
  - formale Unterscheidung synchron / asynchron durch Kausalrelation (synchron: Abhängigkeit des Senders vom Empfänger)

Modeling Synchronous Communication

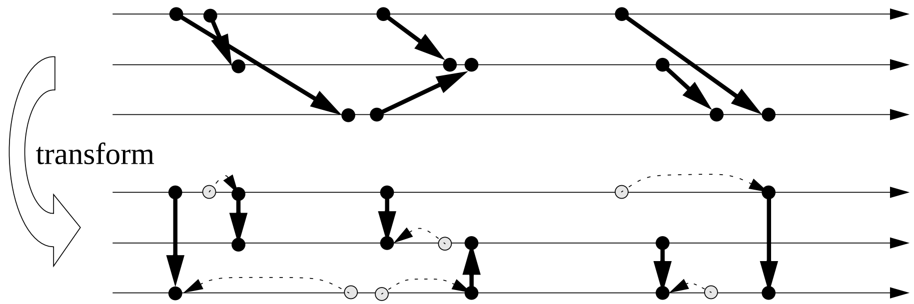
- How do we *define* distributed computations with synchronous message passing?
  - or: *characterize* those distributed computations that can be *realized* with synchronous communications?

- Proposition:
  Synchronous = virtually simultaneous
  = as if msg transmission were instantaneous



  - But: aren't instantaneous message transmissions unrealistic?

- Can we *always* apply a suitable rubber band transformation such that all message arrows become vertical?



“As if” Messages were Instantaneous?

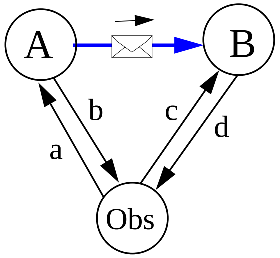
If for a distributed computation a phenomenon can be observed which is impossible with instantaneous messages, the computation must not be realizable with synchronous message passing semantics

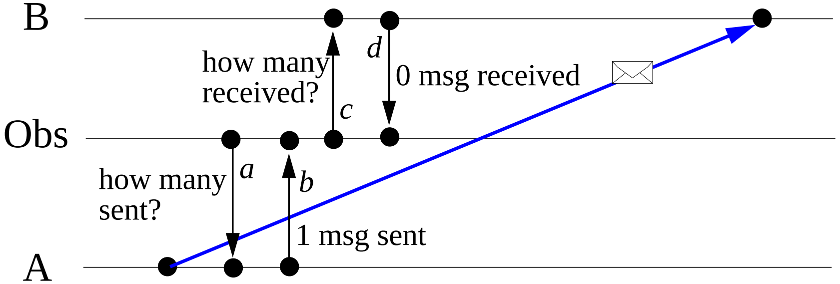
==> message passing should then not be called “synchronous”

Example:

The observer first asks A about the number of messages it sent to B

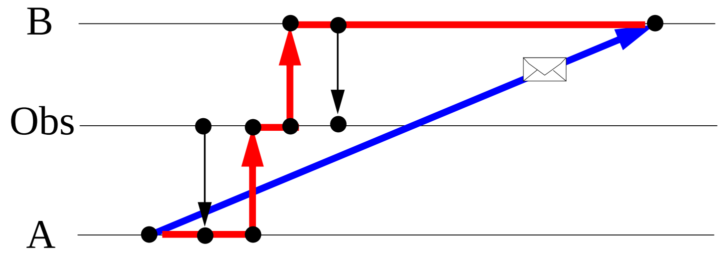
Then it asks B about the number of messages it received from A





Observer learns that a message from A to B is *in transit* for a certain *duration* ==> not synchronous!

Vertical Message Arrows?

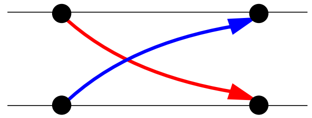


- The message from A to B is *overtaken in an indirect way* by a *chain* of other messages

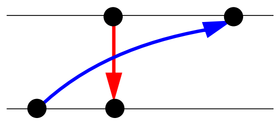
- The direct message can therefore *not be made vertical* by a rubber band transformation

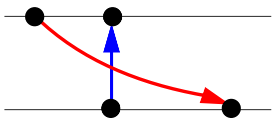
  (A message of the chain would then go backwards in time)

- Another computation which is not possible with synchronous communications (==> deadlock):



Although each *single* arrow can be made vertical, it is not possible to draw the diagram in such a way that *both* arrows are vertical!





Various Characterizations of Synchronous Communications

- Question: are they all equivalent?
- Note: some characterizations are informal or less formal than others

1) Best possible approximation of *instantaneous* communications

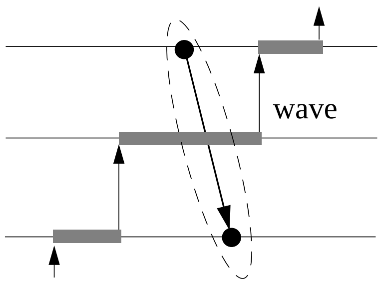
(i.e., without clocks, it is not possible to prove that a message was not transmitted instantaneously)

2) Space-time diagrams can be drawn such that *<u>all</u> message arrows are vertical*

3) *Communication channels* always appear to be *empty*

(i.e., messages are never seen to be in transit)

4) Corresponding *send-receive events* form one *single atomic action*

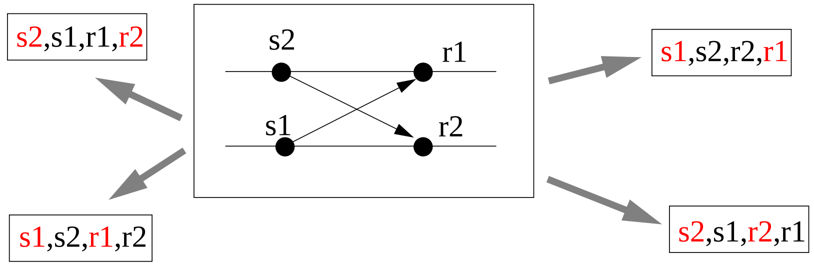


- But what exactly does "atomic" mean?
- Does the combined event happen before or after the wave? Should this be possible with synchronous communication?

set of all events with the causality relation

which belong to the same message

5) ∃ *linear extension* of (E, <) such that ∀ corresponding communic. events s,r: *r is an immedate predecessor of s*



- The example has 4 different linearizations: in all of them a pair of corresponding send-receive events is separated by other events - hence this computation cannot be realized synchronously
- Motivation: corresponding events form a single atomic action

6) Define a (transitive) *scheduling relation* '<' on messages:

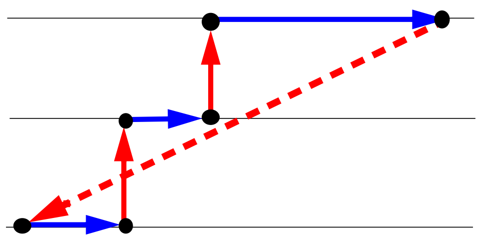
m '<' n iff send(m) < receive(n)

The graph of '<' must be *cycle-free*

this is the classical causality relation on the set of events

- Then whole messages (i.e., corresponding send-receive events s, r) can be scheduled at once (s before r), otherwise this is not possible

7) *No cycle* is possible by moving along *message arrows in either direction*, but always from left to right on process lines



- *Interpretation*: ignoring the direction of message arrows ==>
  - send / receive is "symmetric"
  - "identify" send / receive

- If such a cycle exists ==> no "first" message to schedule
- If no such cycle does exists ==> message schedule exists

8) Synchronous causality relation << is a *partial order*

Definition of << : compare this to the classical causality relation!

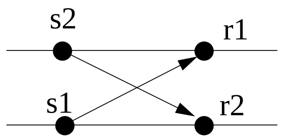
1. If a before b on the same process, then a << b
2. x << s iff x << r ("common past")
3. s << x iff r << x ("common future")
4. Transitive closure

for all corresp. s, r and for all events x

Interpretation: corresponding s, r are not related, but with respect to the synchronous causality relation they are "identified"

they have the same past and future

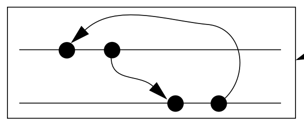
Example:



a) s1 << r2 (1)
b) r1 << r2 (a, 3)
c) s2 << r1 (1)
d) r2 << r1 (b, 3)

cycle, but r1 $\neq$ r2 !

- Compare this characterization to characterization 6
- Why is the definition of << sensible?



This is something where the classical causality relation < is not a partial order, therefore it is not even realizable as a computation with *asynchronous* messages!

Further reading (for those who are interested): Charron-Bost, Mattern, Tel: *Synchronous, Asynchronous and Causally Ordered Communication.* Distributed Computing, Vol. 9 No. 4, pp. 173 - 191, 1996
http://www.informatik.tu-darmstadt.de/VS/Publikationen/papers/syn_asy.ps