Distributed Systems

Group Membership and View Synchronous Communication

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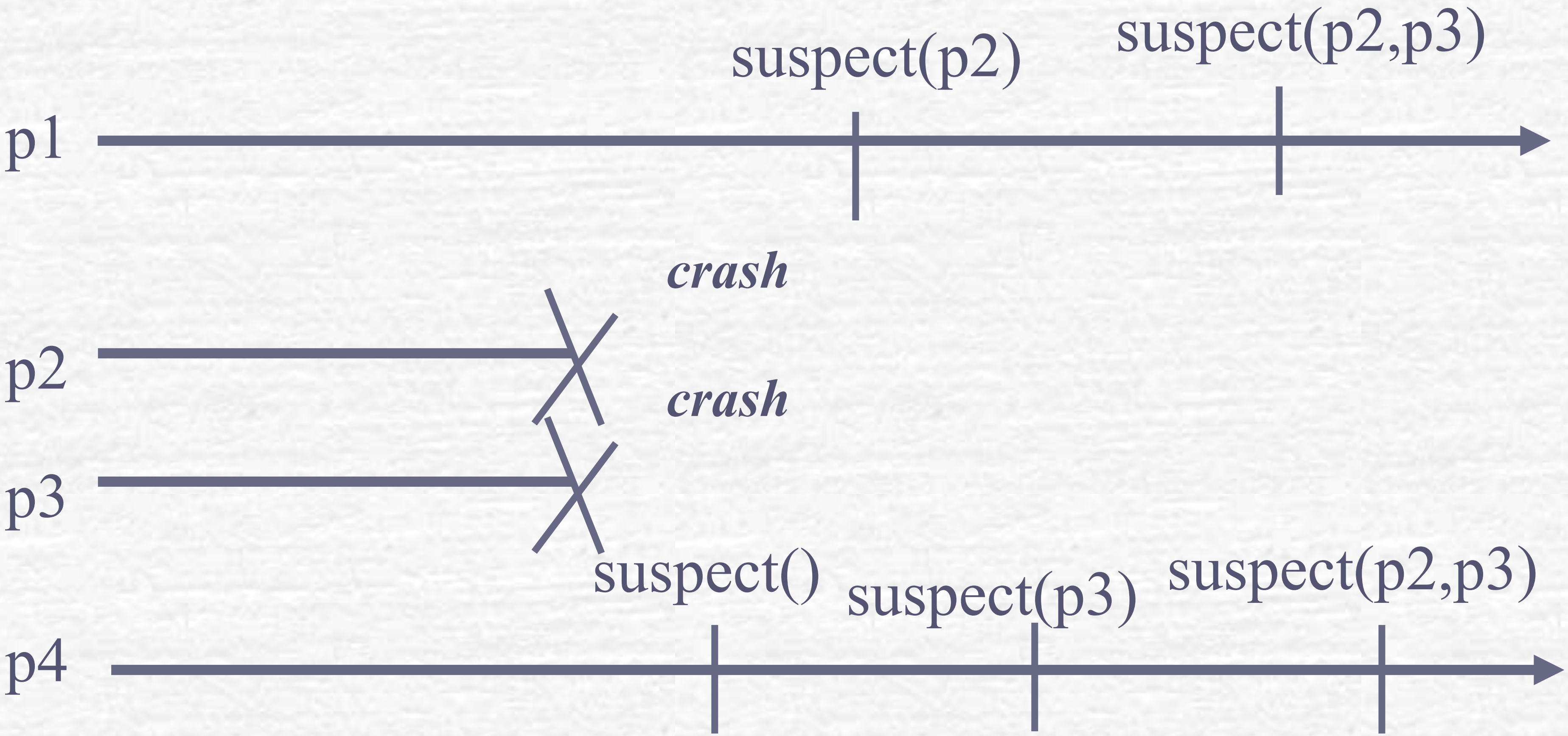
Group Membership

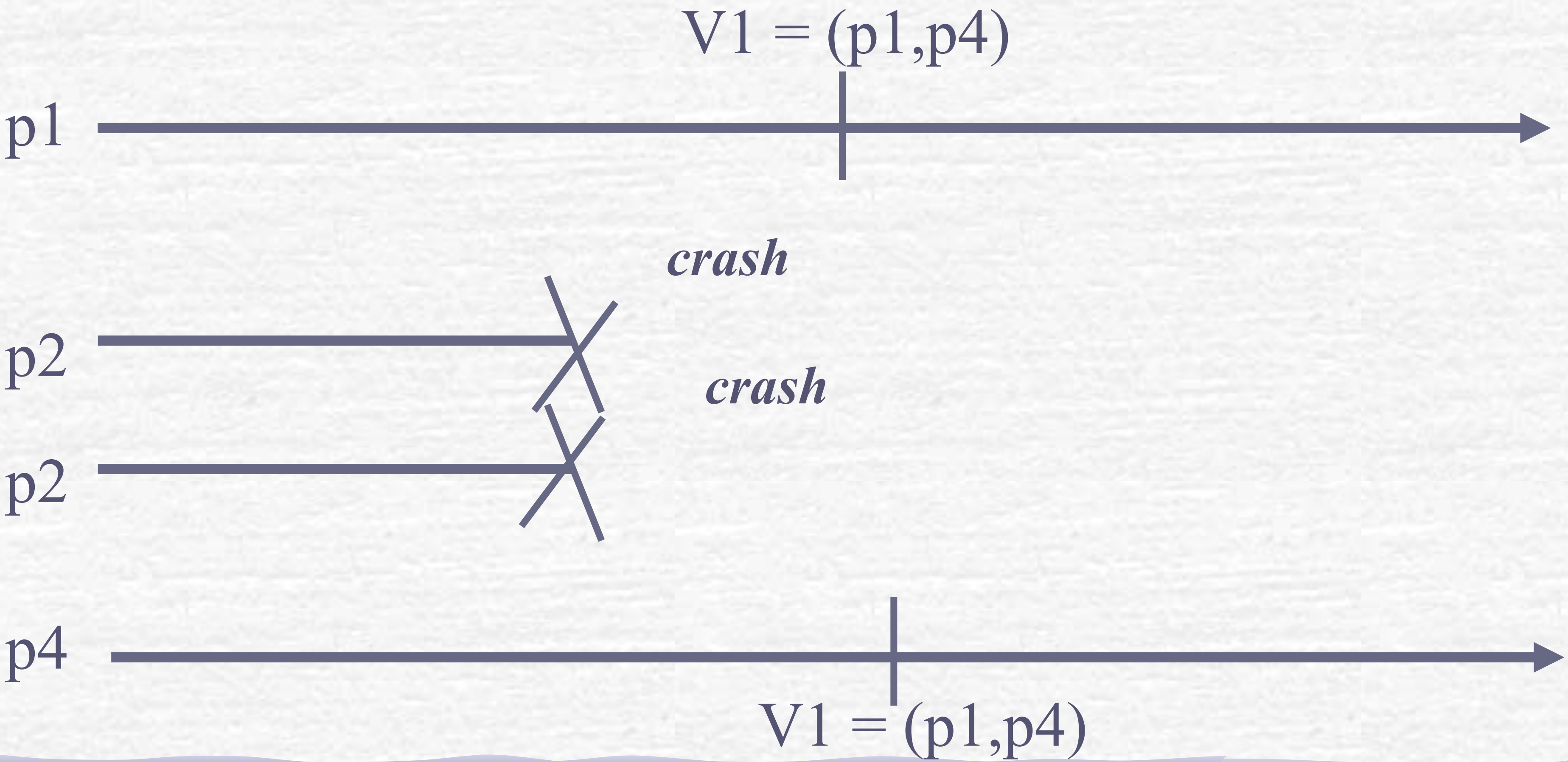
Group Membership

- In some distributed applications, processes need to know which processes are ***participating*** in the computation and which are not
- Failure detectors provide such information; however, that information is ***not coordinated*** (see next slide) even if the failure detector is perfect

Perfect Failure Detector



Group Membership



Group Membership

- To illustrate the concept, we focus here on a group membership abstraction to coordinate the information about ***crashes***

- In general, a group membership abstraction can also typically be used to coordinate the processes ***joinning*** and ***leaving*** explicitly the set of processes (i.e., without crashes)

Group Membership

- ***Like*** with a failure detector, the processes are informed about failures; we say that the processes ***install views***
- ***Like*** with a perfect failure detector, the processes have accurate knowledge about failures
- ***Unlike*** with a perfect failure detector, the information about failures are ***coordinated***: the processes install the same sequence of views

Group Membership

Memb1. Local Monotonicity: If a process installs view (j,M) after installing (k,N), then $j > k$ and $M < N$

Memb2. Agreement: No two processes install views (j,M) and (j,M') such that $M \neq M'$

Memb3. Completeness: If a process p crashes, then there is an integer j such that every correct process eventually installs view (j,M) such that $p \notin M$

Memb4. Accuracy: If some process installs a view (i,M) and $p \notin M$, then p has crashed

Group Membership

- ***Events***
  - Indication: <membView, V>

- ***Properties:***
  - ***Memb1, Memb2, Memb3, Memb4***

Algorithm (gmp)

- **Implements:** groupMembership (gmp).
- **Uses:**
  - PerfectFailureDetector (P).
  - UniformConsensus(Ucons).
- **upon event** < Init > **do**
  - view := (0,S);
  - correct := S;
  - wait := true;

Algorithm (gmp – cont’d)

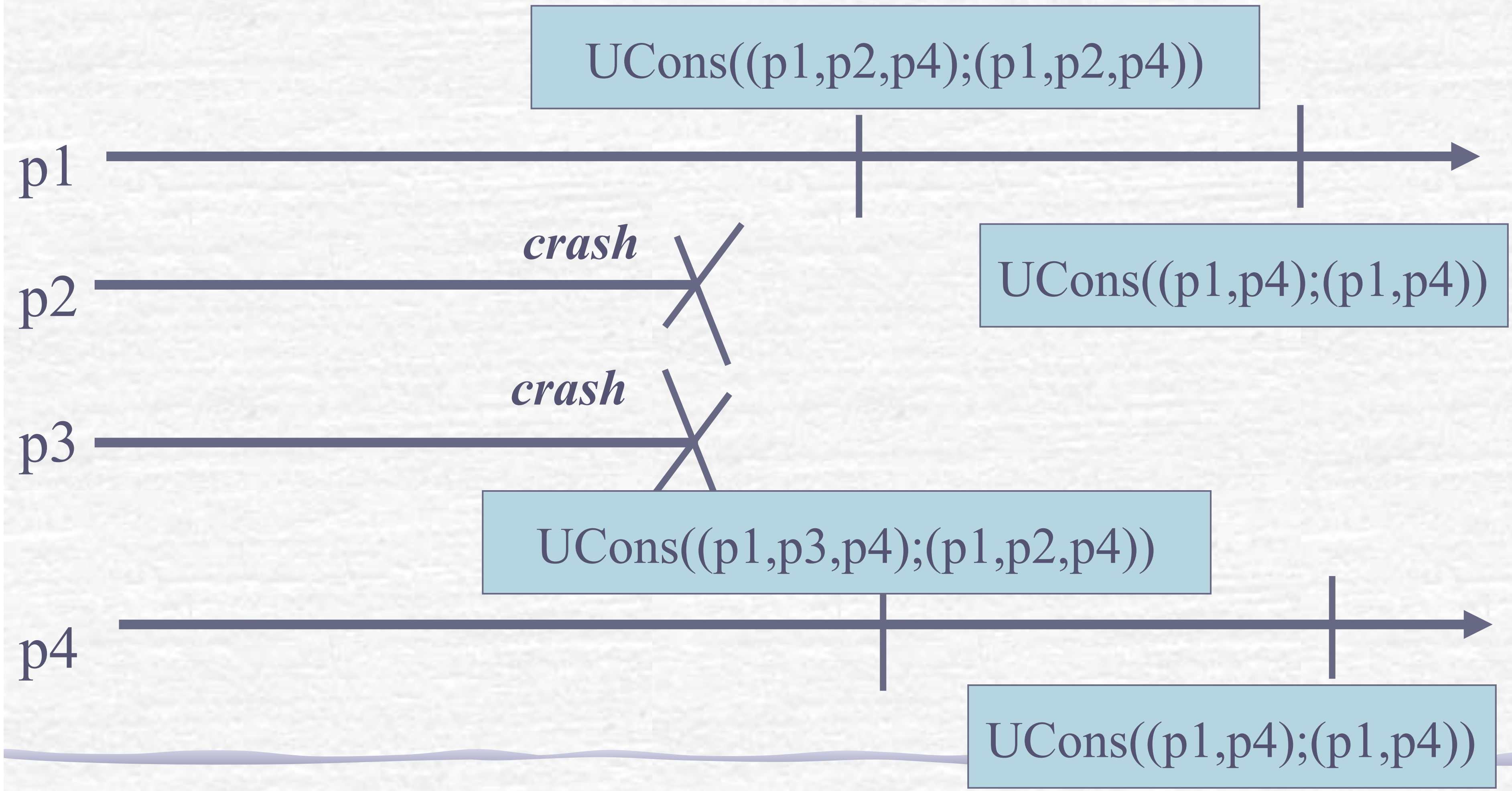
- **upon event** < crash, pi > **do**
  - correct := correct \ {pi};

- **upon event** (correct < view.memb) and (wait = false) **do**
  - wait := true;
  - **trigger**<ucPropose,(view.id+1,correct) >;

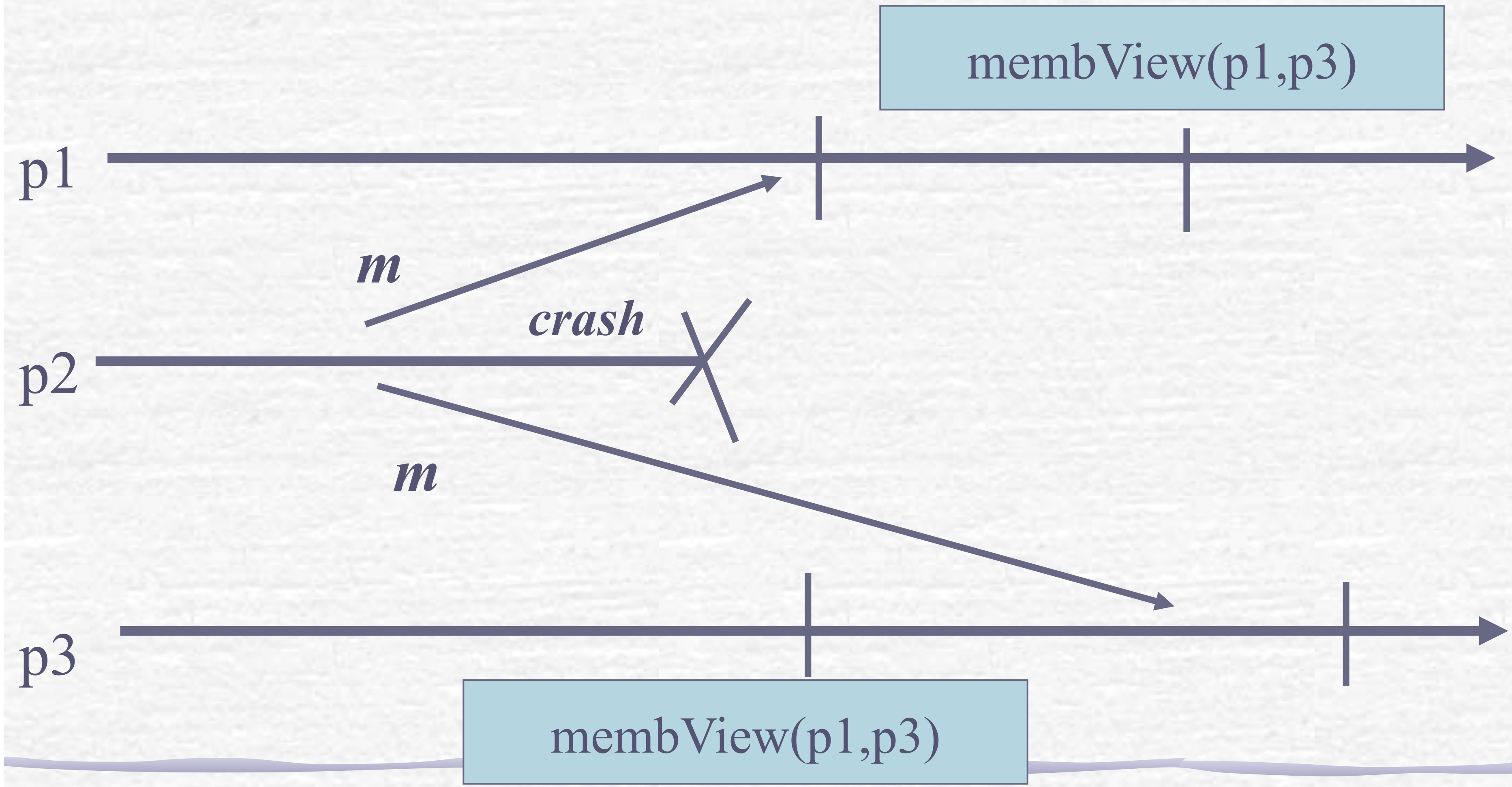
Algorithm (gmp – cont'd)

- **upon event** < ucDecided, (id, memb)> **do**
  - view := (id, memb);
  - wait := false;
  - **trigger** < membView, view>;

Algorithm (gmp)



Group Membership and Broadcast



View Synchrony

- ***View synchronous broadcast*** is an abstraction that results from the combination of group membership and reliable broadcast

- ***View synchronous broadcast*** ensures that the delivery of messages is coordinated with the installation of views

View Synchrony

Besides the properties of ***group membership (Memb1-Memb4)*** and ***reliable broadcast (RB1-RB4)***, the following property is ensured:

VS: A message is ***vsDelivered*** in the view where it is ***vsBroadcast***

View Synchrony

- ***Events***
  - Request:
    - <vsBroadcast, m>
  - Indication:
    - <vsDeliver, src, m>
    - <vsView, V>

View Synchrony

If the application keeps ***vsBroadcasting*** messages, the ***view synchrony*** abstraction might never be able to ***vsInstall*** a new view; the abstraction would be impossible to implement

We introduce a specific event for the abstraction to ***block*** the application from ***vsBroadcasting*** messages; this only happens when a process crashes

View Synchrony

- ***Events***
  - Request:
    - <vsBroadcast, m>; <vsBlock, ok>
  - Indication:
    - <vsDeliver, src, m>; <vsView, V>; <vsBlock>

Algorithm (vsc)

- **Implements:** ViewSynchrony (vs).
- **Uses:**
  - GroupMembership (gmp).
  - TerminatingReliableBroadcast(trb).
  - BestEffortBroadcast(beb).

Algorithm (vsc – cont'd)

- **upon event** < Init > **do**
  - view := (0,S); nextView := ⊥;
  - pending := delivered := trbDone := ∅;
  - flushing := blocked := false;

Algorithm (vsc – cont'd)

- **upon event** <vsBroadcast,m> and (blocked = false) **do**
  - delivered := delivered ∪ { m }
  - **trigger** <vsDeliver, self, m>;
  - **trigger** <bebBroadcast, [Data,view.id,m>;

Algorithm (vsc – cont'd)

- **upon event**<bebDeliver,src,[Data,vid,m]) **do**
  - If(view.id = vid) and (m ∉ delivered) and (blocked = false) then
    - delivered := delivered ∪ { m }
  - **trigger** <vsDeliver, src, m >;

Algorithm (vsc – cont'd)

- **upon event** < membView, V > **do**
  - addtoTail (pending, V);
- **upon** (pending ≠ ∅) and (flushing = false) **do**
  - nextView := removeFromhead (pending);
  - flushing := true;
  - **trigger** <vsBlock>;

Algorithm (vsc – cont'd)

- **Upon** <vsBlockOk> **do**
  - blocked := true;
  - trbDone:= ∅;
  - **trigger** <trbBroadcast, self, (view.id,delivered)>;

Algorithm (vsc – cont'd)

- **Upon** <trbDeliver, p, (vid, del)> **do**
  - trbDone := trbDone $\cup$ {p};
  - **forall** m $\in$ del and m $\notin$ delivered **do**
    - delivered := delivered $\cup$ { m };
  - **trigger** <vsDeliver, src, m >;

Algorithm (vsc – cont'd)

- **Upon** (trbDone = view.memb) and (blocked = true) **do**
  - view := nextView;
  - flushing := blocked := false;
  - delivered := ∅;
  - **trigger** <vsView, view>;

Consensus-Based View Synchrony

Instead of launching parallel instances of TRBs, plus a group membership, we use one consensus instance and parallel broadcasts for every view change

Roughly, the processes exchange the messages they have delivered when they detect a failure, and use consensus to agree on the membership and the message set

Algorithm 2 (vsc)

- **Implements:** ViewSynchrony (vs).
- **Uses:**
  - UniformConsensus (uc).
  - BestEffortBroadcast(beb).
  - PerfectFailureDetector(P).

Algorithm 2 (vsc – cont'd)

- **upon event** < Init > **do**
  - view := (0,S);
  - correct := S;
  - flushing := blocked := false;
  - delivered := dset := ∅;

Algorithm 2 (vsc – cont'd)

- **upon event** <vsBroadcast,m) and (blocked = false) **do**
  - delivered := delivered $\cup \{ m \}$
  - **trigger** <vsDeliver, self,m>;
  - **trigger** <bebBroadcast,[Data,view.id,m] >;

Algorithm 2 (vsc – cont'd)

- **upon event**<bebDeliver,src,[Data,vid,m]) **do**
  - **if** (view.id = vid) and m $\notin$ delivered and blocked = false **then**
    - delivered := delivered $\cup$ { m }
  - **trigger** <vsDeliver, src, m >;

Algorithm 2 (vsc – cont'd)

- **upon event** < crash, p > **do**
  - correct := correct \ { p };
  - **if** flushing = false **then**
    - flushing := true;
    - **trigger** <vsBlock>;

Algorithm 2 (vsc – cont'd)

- **Upon** <vsBlockOk> **do**
  - blocked := true;
  - **trigger** <bebBroadcast, [DSET,view.id,delivered] >;

Algorithm 2 (vsc – cont'd)

- **Upon** <bebDeliver, src, [DSET,vid,del] > **do**
  - dset:= dset ∪ (src,del);
  - **if forall** p ∈ correct, (p,mset) ∈ dset **then** **trigger** <ucPropose, view.id+1, correct, dset >;

Algorithm 2 (vsc – cont'd)

- **Upon** <ucDecided, id, memb, vsdset > **do**
  - **forall** (p,mset) $\in$ vsdset: p $\in$ memb **do**
  - **forall** (src,m) $\in$ mset: m $\notin$ delivered **do**
    - delivered := delivered $\cup$ $\{$m$\}$
    - **trigger** <vsDeliver, src, m>;
  - view := (id, memb); flushing := blocked := false; dset := delivered := $\emptyset$;
  - **trigger** <vsView, view>;

Uniform View Synchrony

We now combine the properties of

group membership (Memb1-Memb4) – which is already uniform

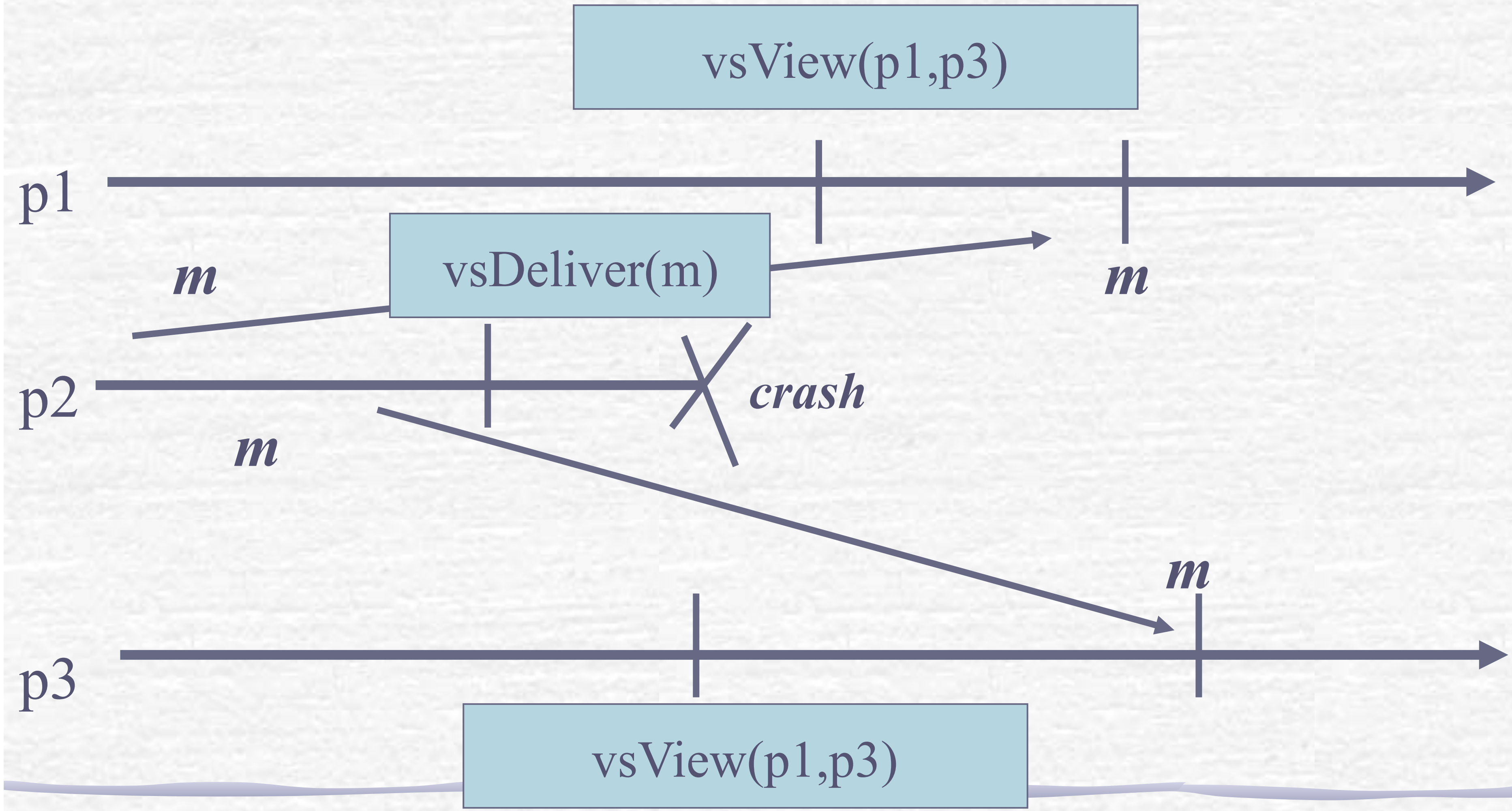
uniform reliable broadcast (RB1-RB4) – which we require to be uniform

VS: A message is ***vsDelivered*** in the view where it is ***vsBroadcast*** – which is already uniform

Uniform View Synchrony

Using uniform reliable broadcast instead of best effort broadcast in the previous algorithms does not ensure the uniformity of the message delivery

Uniformity?



Algorithm 3 (uvsc)

- **upon event** < Init > **do**
  - view := (0,S);
  - correct := S;
  - flushing := blocked := false;
  - udelivered := delivered := dset := $\emptyset$;
  - for all m: ack(m) := $\emptyset$;

Algorithm 3 (uvsc – cont'd)

- **upon event** <vsBroadcast,m) and (blocked = false) **do**
  - delivered := delivered ∪ {m};
  - **trigger** <bebBroadcast,[Data,view.id,m] >;

Algorithm 3 (uvsc – cont'd)

- **upon event**<bebDeliver,src,[Data,vid,m]) **do**
  - **if** (view.id = vid) **then**
    - ack(m) := ack(m) ∪ {src};
  - **if** m ∉ delivered **then**
    - delivered := delivered ∪ { m }
  - **trigger** <bebBroadcast, [Data,view.id,m] >;

Algorithm 3 (uvsc – cont'd)

- **upon event** (view ≤ ack(m)) and (m ∉ udelivered) **do**
  - udelivered := udelivered ∪ { m }
  - **trigger** <vsDeliver, src(m), m >;

Algorithm 3 (uvsc – cont'd)

- **upon event** < crash, p > **do**
  - correct := correct \ { p };
  - **if** flushing = false **then**
    - flushing := true;
    - **trigger** <vsBlock>;

Algorithm 3 (uvsc – cont’d)

- **Upon** <vsBlockOk> **do**
  - blocked := true;
  - **trigger** <bebBroadcast, [DSET,view.id,delivered] >;

- **Upon** <bebDeliver, src, [DSET,vid,del] > **do**
  - dset:= dset ∪ (src,del);
  - **if forall** p ∈ correct, (p,mset) ∈ dset **then trigger** <ucPropose, view.id+1, correct, dset >;

Algorithm 3 (uvsc – cont'd)

- **Upon** <ucDecided, id, memb, vsdset > **do**
  - **forall** (p,mset) $\in$ vs-dset: p $\in$ memb **do**
  - **forall** (src,m) $\in$ mset: m $\notin$ udelivered **do**
    - udelivered := udelivered $\cup$ {m}
    - **trigger** <vsDeliver, src, m>;
  - view := (id, memb); flushing := blocked := false; dset := delivered := udelivered := $\emptyset$;
  - **trigger** <vsView, view>;