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MODULE CausalNetwork
EXTENDS BasicNetwork, Naturals

VARIABLES
  vc  vc[r][s] denotes the latest message from s ∈ Replica observed by r ∈ Replica

ts(m)  ≜ m.lvc  timestamp (vector clock) for m
sender(m)  ≜ m.aid.r  the replica that sends m
Max(a, b)  ≜ IF a > b THEN a ELSE b

CNTypeOK  ≜
  ∧ SMTTypeOK
  ∧ vc = [r ∈ Replica ↦ [Replica → Nat]]  vc[r] : vector clock at r ∈ Replica

CNInit  ≜
  ∧ BInit
  ∧ vc = [r ∈ Replica ↦ [s ∈ Replica ↦ 0]]  ∀ r, s, vc[r][s] = 0

CNBroadcast(r, m)  ≜
  ∧ vc' = [vc EXCEPT ![r][r] = @ + 1]
  ∧ LET cm ≜ [m EXCEPT !.lvc = vc'[r]]
  IN  BNBroadcast(r, cm)

CNCausallyReady(r, m)  ≜  whether m is causally ready to be delivered by r ∈ Replica
  LET mr ≜ sender(m)
  IN  ∧ ts(m)[mr] ≤ vc[r][mr] + 1
      ∧ ∀ s ∈ Replica \ {mr} : ts(m)[s] ≤ vc[r][s]

CNDeliver(r)  ≜
  ∧ incoming[r] ≠ {}
  ∧ ∃ m ∈ incoming[r] :
    ∧ CNCausallyReady(r, m)
    ∧ LET mr ≜ sender(m)
      IN  vc' = [vc EXCEPT ![r][mr] = Max(@, ts(m)[mr])]  update vc[r]
    ∧ lmsg' = [lmsg EXCEPT ![r] = m]
  ∧ UNCHANGED ⟨incoming⟩

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\ * Last modified Tue Jun 18 12:38:28 CST 2019 by xhdn
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