Distributed Systems

- Distributed versus Parallel
  - Loosely coupled vs. tightly coupled
    - » shared memory
    - » synchronized clocks, global clocks
    - » network topology
      - fully connected,
      - partially connected, e.g. ring, tree, star, k-connected
    - » network communication
      - point-to-point
      - CSMA/CD (Carrier Sense Multiple Access, Collision Detect)

Distributed Systems

- Reliability of Distributed/Parallel Systems
  - Harper and Lala 1991
    - » The assertion is often made that parallel processors are intrinsically reliable, fault tolerant, and reconfigurable due to their multiplicity of processing resources. In fact, the only intrinsic attribute guaranteed by multiple processors is a higher total failure rate.
  - We will investigate this especially with respect to RAID systems
  - Individual workstation MTBF (Pra96, table 3.2, pg 136)
    - » (this info is dated, but gives you an idea...)
    - » DEC 35,872h 35h
    - » HP 58,700h 58h
    - » SUN 40,601h 40h
    - » IBM AP101S 20,000h 20h

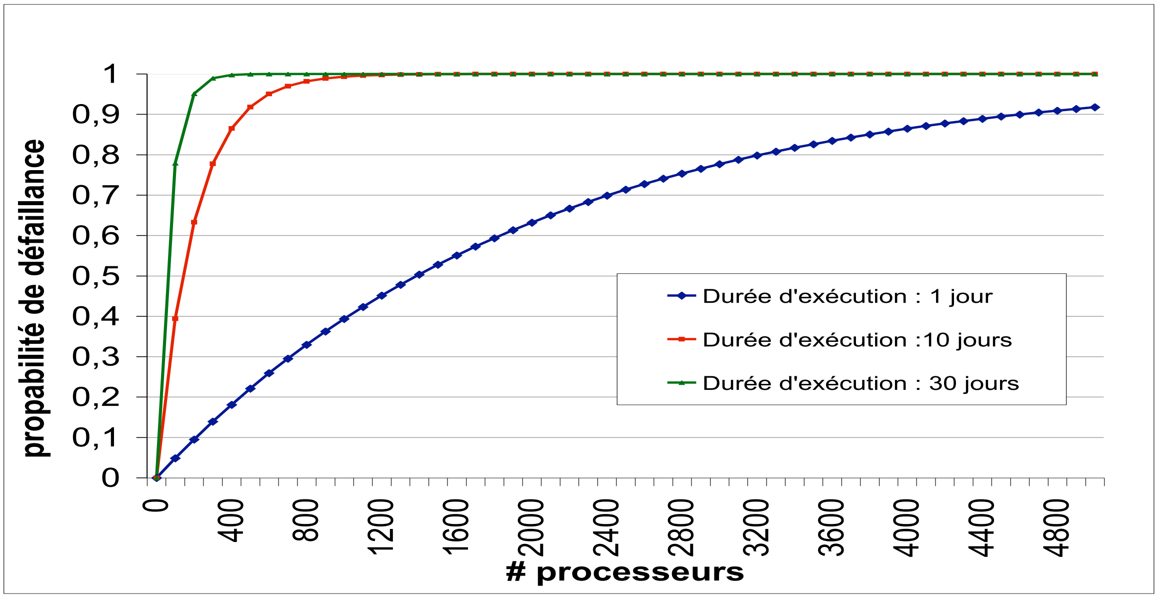
Unreliability in the absence of FT

Computation on Cluster

MTBF = 2000 days (48,000h, approx. 5 1/2 years)

Unreliability of one node: $F(t) = 1 - R(t) = 1 - e^{-t}$

Figure source: Jafar, Krings, Gautier and Roch, EIT 2005



Distributed Systems

- Design Issues
  - circuit and technology level
    - radiation robust components, gallium arsenide chips
    - circuit designed for testability and reliability
  - node-level architecture
    - design of VLSI
  - internode architecture
    - node connections and configurations, reconfiguration in the presence of faults
  - operating system
    - fault recovery, e.g. rollback procedure
    - load balancing
  - application level
    - checks on results, signatures, bounds

Distributed Systems

- Asynchronous Message Passing
  - send(data, destination)
  - receive(data, source)
  - receive(message)
    - source is extracted from message itself
  - queuing messages => finite buffers
    - in reality no pure asynchronous message passing exists
    - with finite buffer receiver may block

Distributed Systems

- Synchronous Message Passing
  - no buffering
  - guards
    - execute statements if the guards are "true"
  - alternative construct
    - list of guarded statements
    - non-determinism
  - CSP (Communicating Sequential Processes)
    - to send a message:

      P ! message
    - to receive a message:

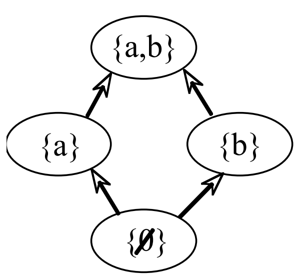
      P ? message

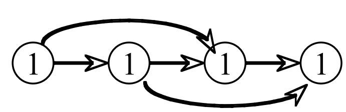
Distributed Systems

- Remote Procedure Call (RPC)
  - the service to be provided by the server is treated as a procedure that resides on the machine on which the server is located.
  - failure during communication
    - unwanted executions called orphans
      - a client that crashes during an RPC and restarts on recovery may reissue the call to the server, even though the earlier call is still being executed by the server

Ordering -- Synchronizing

- Which event happened first?
  - When events happen on distributed systems it is often not clear which events happened first.
- Partial Order
  - A partial order is a Relation *R,* that is
    - irreflexive, i.e. $(a,a) \notin R$ for any a and
    - transitive, i.e. $(a,b)(b,c) \Rightarrow (a,c)$
- Partial Order and Total Order





Ordering -- Synchronizing

- Define "happened-before" as partial order

$a \rightarrow b \equiv a$ happened before b

$a \rightarrow b \quad b \rightarrow c \Rightarrow a \rightarrow c$

$a \not\rightarrow b \quad b \not\rightarrow c \Rightarrow$ events are concurrent

  - Note, PO does not define a total order

Ordering -- Synchronizing

- Logical Clock

Let C_i denote the logical clock for process P_i

$C_i(a)$ is the value associated with event a of P_i

- Clock Conditions
  - C1: if a & b are events in process P_i ,
    - and a comes before b,
    - then $C_i(a) < C_i(b)$
  - C2: if a is the sending of a message by process P_i and b is the receipt of that message by process P_j ,
    - then $C_i(a) < C_j(b)$

Ordering -- Synchronizing

- Satisfy C1:
  - each P_i increments C_i between any two successive events

- Satisfy C2:
  - if event a is the sending of a message m by P_i, then m contains a time-stamp T_m, with $T_m = C_i(a)$
  - upon receiving of m, process P_j sets C_j greater than or equal to its present value and greater than T_m .

- Logical clocks have no relationship to actual, physical clocks