Fail-Stop Processes

- Discussion based on
  - Byzantine Generals in Action: Implementing Fail-Stop Processors, Fred B. Schneider, ACM Transactions on Computer Systems, Vol. 2, No..2, pp. 145-154, May 1984.
  - Reasons why this paper is still of interest.
  - What would it take to guarantee that a fault will be benign?

Fail-Stop Processes

- FSP-Properties
  - Halt-on-Failure Property
    - It will halt before performing an erroneous state transition visible to other proc's.
  - Failure Status Property
    - Any non-faulty process can detect the halting of any other process.
  - Stable Storage Property
    - Part of the processes memory is "stable", i.e.
      - unaffected by failure
      - readable by other processors

Fail-Stop Processes

- Given FSPs, design a reliable system
  - Non-trivial problem! (e.g. Hypercube)
    - needs re-routing (optimal)
    - reconfiguration
    - reallocation
- How does one implement a FSP?
  - Impossible with finite hardware
  - Build a k-FSP
  - Fails safe for $f \leq k$

Fail-Stop Processes

- Assume stable storage, then the behavior of a FSP is characterized by:

  IF k+1 requests AND
  requests are identical AND
  requests are from different processes AND
  NOT failed

  THEN
  process operation

  ELSE
  failed=TRUE

- Stable storage assumption may be quite optimistic.
- Special design-considerations are necessary.

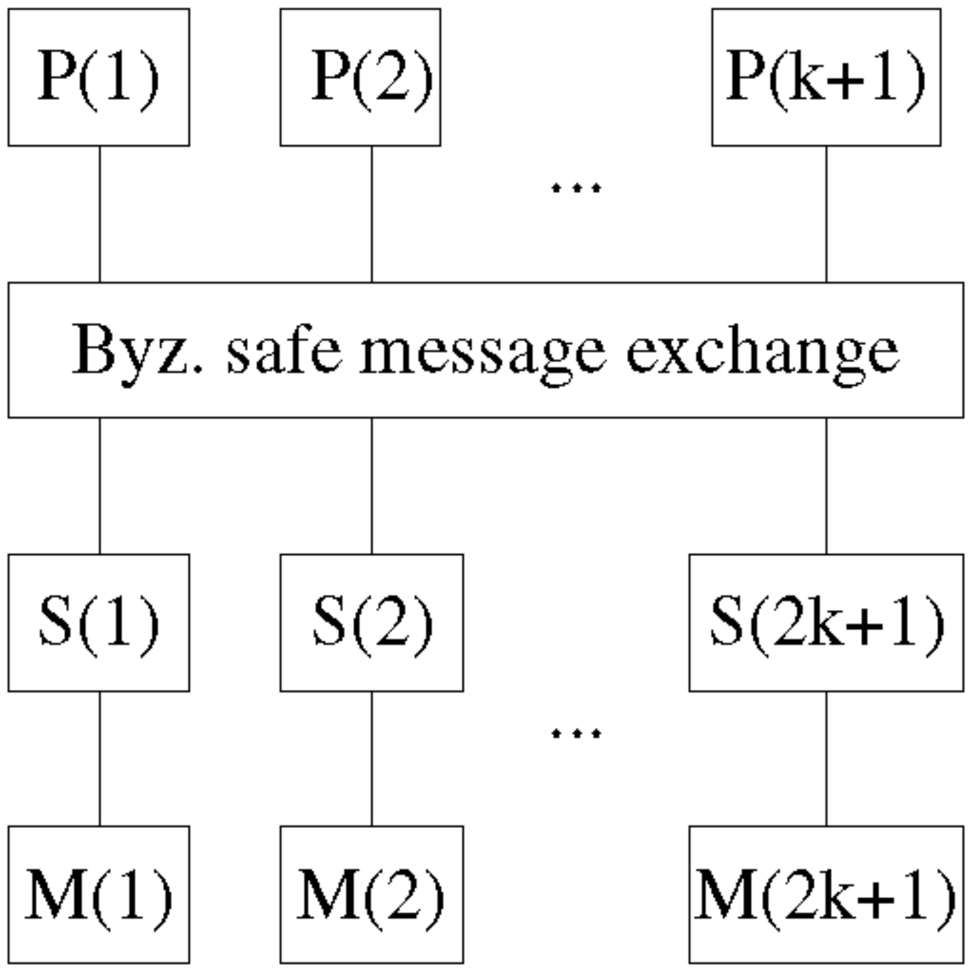
Fail-Stop Processes

– K-FSP are based on two types of real processes

1. $P(FSP) = \{P_1, P_2, ..., P_{k+1}\}$
   - e.g. usual definition of a processor (CPU)
2. Storage processes $S(FSP) = \{S_1, P_2, ..., S_{2k+1}\}$
   - memory unit
   - memory management

Fail-Stop Processes

– Block Diagram



Fail-Stop Processes

- Assumptions
  - Network Assumptions
    - Messages are delivered uncorrupted
    - Origin of messages can be authenticated by receiver
  - Operating Assumptions
    - Ps fail independently
    - Failure of P is detected by S-Processes when P-Processes try to write.
    - Disagreement on a write request is confirmed by the S-Processes.
    - Agreement on a request must be reached before executing the write.
    - Only $M_1, M_2, \ldots, M_{2k+1}$ are visible to outside (of FSP).

Fail-Stop Processes

- Redundant in all P-Processes:
  - P broadcasts write request to all S's
  - S's exchange values+vote (Byzantine safe). P is commander, S's are lieutenants.
- Operation

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IF
        all S agree
THEN
        write
ELSE
        stop machine
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Fail-Stop Processes

- Stable Storage
  - Majority of copies are correct and identical.
  - A non-faulty FSP can always write to its own stable storage.
  - Any non-faulty process can read any stable storage.
  - Value of a memory location is $maj(M_1, \ldots , M_{2k+1})$
  - An S-proc can write:

    IF exactly 1 request is received from each P

    AND all proc's are identical

    THEN write

    ELSE set a "failed" flag in memory and stop

Fail-Stop Processes

- On the Number of Processors
  - Assume the application needs N processors
    - If we want to tolerate k faults we need $N + k$ FSPs
    - i.e. $(N + k)$ k-FSPs
  - Naive implementation
    - to implement 1 FSP
      - $k + 1$ P-Proc's and $2k + 1$ S-Proc's $= 3k + 2$
    - then to implement the $N+k$ FSPs
      - $(N + k)(3k + 2)$ that's a lot of processors!

Fail-Stop Processes

- It could be considered wasteful to dedicate an entire processor to running an S-Process.
- Therefore assume a single processor is able to run *s* S-Processes.

- Assume P-Proc's are not delayed by choice of s.
  $\Rightarrow$ now need only $\lceil (N+k)/s \rceil (2k+1)$ processors for S-Processes.

- Note: faults not independent anymore.

- But still $2k+1$ replication of S-Processes
  $\Rightarrow$ given k-faults still $k+1 \Rightarrow$ majority!