# *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*

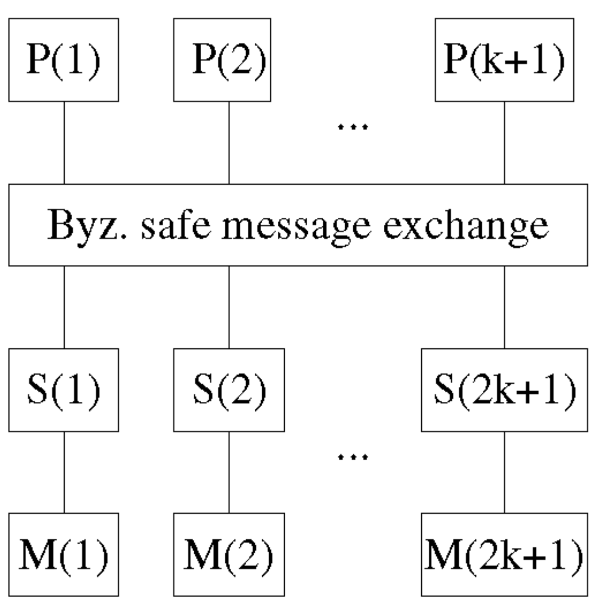
– K-FSP are based on two types of real processes

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

```
IF
        all S agree
THEN
        write
ELSE
        stop machine
```

# *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!