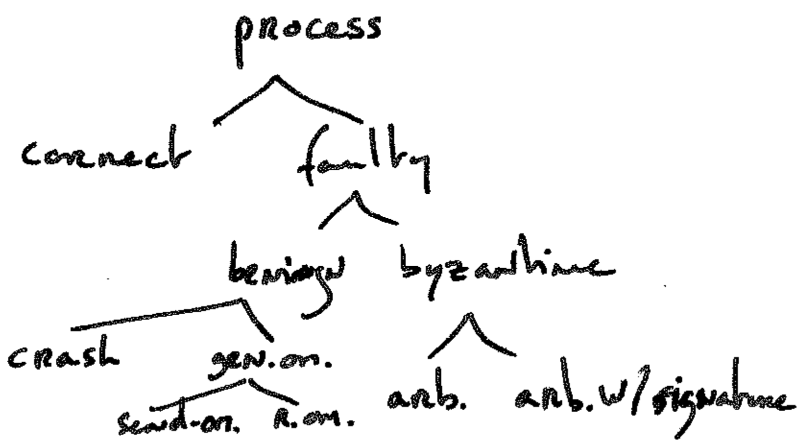
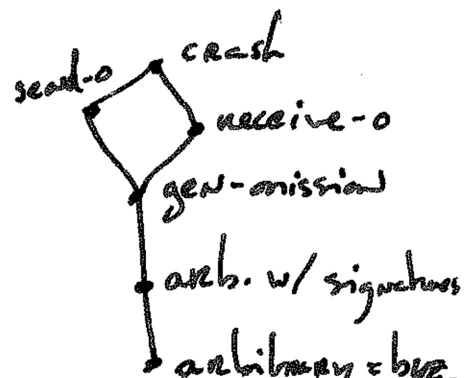
Distributed Computing

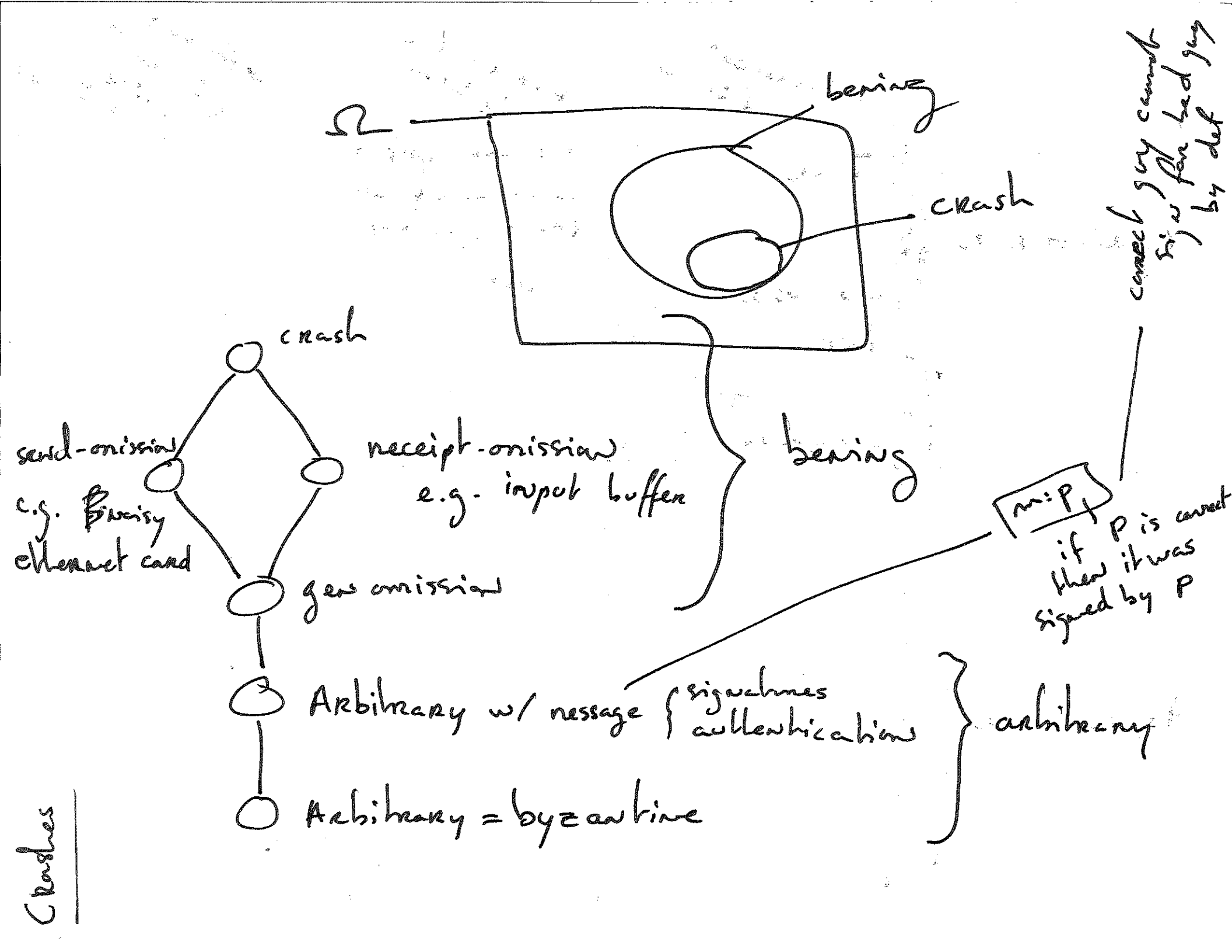
CSC2221

- Setting : synchronous, asynchronous, partially sync.
- Communica° : message passing, shared memory
- Issues : + Atomic Commit
  + Leader election
  + Mutual Exclusion
  + TRB (Validity, Agreement, Integrity)
  + Consensus (V, A, I, Termination)
- Faults :





- Parallel Comp = Classical para comp ∪ dist comp
  - Parallel Comp ↓ concurrency
  - Classical para comp ↓ ~ multithread ~
  - dist comp ↘ external ND, external ~~language~~
    ↓ communica°
    ↓ failures, asynchrony


Ω
benign
crash
correct guy cannot sign for bad guy by def
crash
send-omission
e.g. faulty ethernet card
receipt-omission
e.g. input buffer
benign
m:P
if P is correct then it was signed by P
gen omission
Arbitrary w/ message {signatures authentications}
arbitrary
Arbitrary = byzantine
Crashes

~~multiple broadcast~~

(PS, CS, MO, MBS, AS+R)

1: (1, 1, 0, x, x) ✓ (1, 0, 0, x, x) ×
(1, 0, 1, x, x) ✓

2: (0, 1, X, 1, 1) ✓ (0, 1, 0, X, 0) ×
(0, 1, X, 0, 1) ✓#1

3: (0, X, 1, 1, X) ✓
(0, X, 1, 0, X) ×

Relaxing FLP

PS —
CS —
MO —
MBS — multiple broadcast / drop
AS+R —

Global Coin Proof

→ D e.g.

Round 1:

P_1	P_2	P_3
0	1	1

if $C_1 = 0$, (coin toss was unlucky for agreement)

then strong adversary can prevent P_2 or P_3 to move to round 2 (say P_2)

Round 2:

P_1	P_3
1	0

$C_2 = X$ is learned when P_1 tosses

Round 1:

P_2
$1-X$

strong adv lets P_2 move to round 2

---

wlog $X = 1$ then

P_1	P_2	P_3
1	0	0

and $C_2 = 1$ → repeat forever

$\Rightarrow \varepsilon = 0 \Rightarrow \Omega\left(\frac{1}{\varepsilon}\right) = \Omega(\infty)$

Unreliable Failure Detectors

FLP → transition irrevocable
change bivalence → univalence
depends on right and in processus:

~~→ peut être caché~~

→ synchrone : visible

→ asynchrone : invisible

FLP ⇒ lack of failure detect.

~~asynchronous → ...~~

Failure detector : doesn't lie, report who is on the list _

perfect failure detect.
→ perfect oracle:
complete : ∀ dead, dead ∈ list
accuracy : ∀ x ∈ list, x is dead

Weak FD : ◇W

- ∃t, ∃ connect-p, from t onwards, oracle(connect-p) will say ∀ dead is on dead list
- ∃t, ∃ ——, ∀p, no p suspects connect-p

→ can solve FLP !

Leader Election (Weak FD) — Ω

- ∃t ∃ ∀p→ con-p, ∀p, p trusts con-p

FLP
- → unrel. fail. detect
  - → perfect
  - → unrel.
- → partial synchronous
- → Ben Or (doesn't use 99% of time things go well info)

$\Diamond W \leftrightarrow \Omega$

q(T) → mutual excl. in message passing

→ homework: show $\Diamond W \leq \Omega$

→ scheduler = partially synch ⟷ WeakFD
(w/ relative speed)

perfect failure detect ⟷ ~~perfect FD~~ synch sys.

→ research quest. class of FD beyond Ω-complete
- wait-free

k-set agreement

→ skip impl. 3rd alg for chap 11

Failure Detectors

→ distributed oracle → perfect { complete: $\forall$ dead, dead $\in$ suspects ; accuracy: $\forall s \in$ suspects, s is dead }

→ unreliable (weak FD) { $\exists t, \exists p \in$ connect, front, $oracle^{pc}$ is complete ; $\exists t, \exists$ ___, front, $\forall p \neq pc$, $oracle^{p}$: pc $\notin$ suspect }

weakest FD → $\Diamond W$

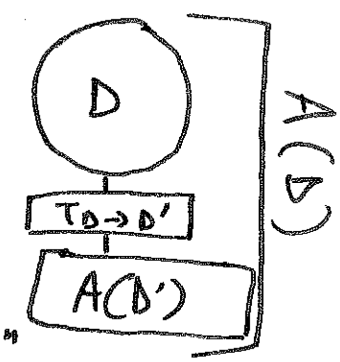
Chandra Toueg classes

$D \subset oracle^{p}$.dead

completeness → $p \in$ connect would not make sense

accuracy \ completeness	strong: $\exists t, \forall p \in C$, ...,	weak: $\exists t, \exists p \in C, D \subset or^{p}.d$
strong: $\forall p \in$ connect, $\forall p' \in C$, $p \notin oracle^{p'}$.dead	P	Q
weak: $\exists p \in C, \forall p' \in C$ $p \notin oracle^{p'}$.dead	S	W
ev. strong: $\exists t$, oracle is str.	$\Diamond P$	$\Diamond Q$
ev. weak: $\exists t$, oracle is weak	$\Diamond S$	$\Diamond W$

Distributed Reduction



Let D and D' be FDs. $D \geq D' \iff \exists T_{D \to D'}$

"D' is red. to D" ⟺ "D' is weaker than D"

Thm $P \geq Q$, $S \geq W$, $\Diamond P \geq \Diamond Q$

Cor $Q \geq P$, etc. → $P \cong Q$

⟹ Consensus solvable in AS with $f < \lceil \frac{n}{2} \rceil$, $\forall D$, $D \geq \Diamond W$

⟹ Consensus not solvable in AS with $f \geq \lceil \frac{n}{2} \rceil$, $\forall D$, $\Diamond P \geq D$

QoS

p monitors q

Wey → { prob. of loss / distrib° + requirements: | $D = 10$ ms, $P_A = .999$ } →

↓

QoS F

Extend

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k-set agreement : generalized consensus
$k = 1$

partial sync : GST