Models

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Models

- abstract from details
- concentrate on functionality, properties, ... that are considered important for a specific system/application
- use model to analyse, prove, predict, ... system properties

- models in engineering disciplines very common, not so in CS
- we'll see many models in lecture: “Real-Time Systems (winter term)”
- today: models to analyse fault tolerance techniques
- objective: understand the need for careful understanding of models

Fault Tolerance

- Techniques how to build reliable systems from less reliable components

- Fault(Error, Failure, ...): synonymously used for "something goes wrong" (more precise definitions and types of faults in SE)

Properties

- Reliability:
  - R(t): probability for a system to survive time t

- Availability:
  - A: fraction of time a system works

Fault Tolerance: key ingredients

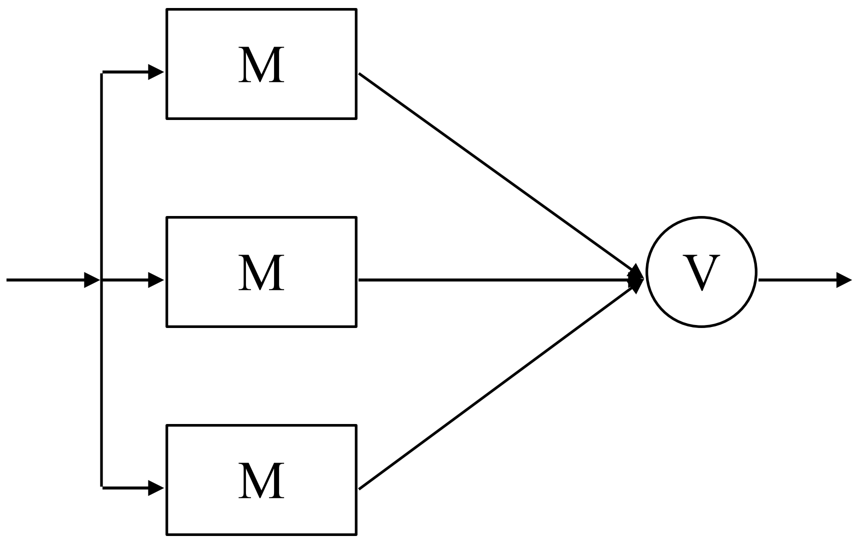
- Fault detection and confinement
- Recovery
- Repair

- Redundancy
  - information
  - time
  - structural
  - functional

Examples: RAID, Triple Modular Redundancy

John v. Neumann

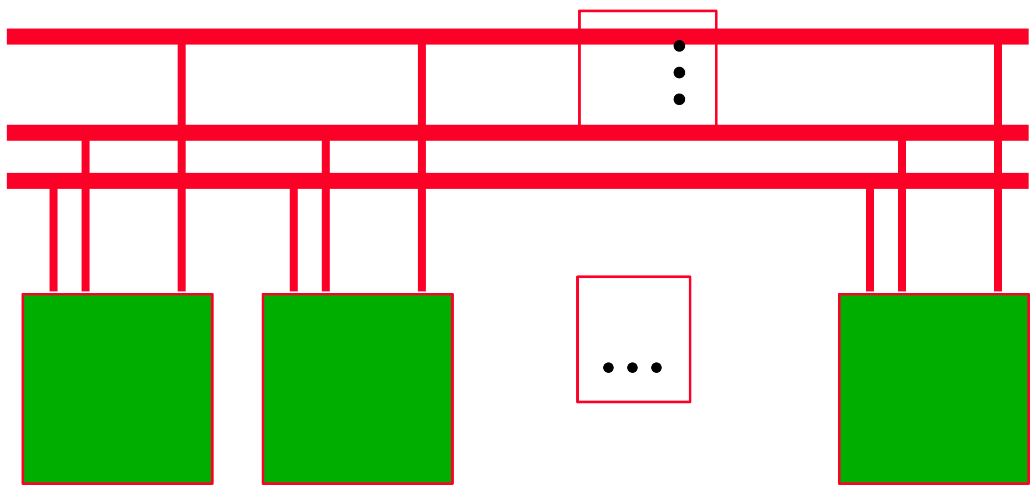
Voter: *single point of failure*



Can we do better ->
distributed solutions ?

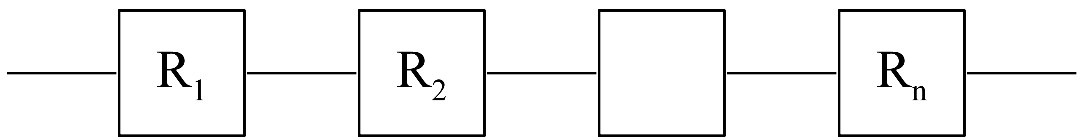
Limits(mathematical) of Reliability, Variant 1

Parallel-Serial-Systems
(Pfitzmann/Härtig 1982)



Reliability Models

Serial System:

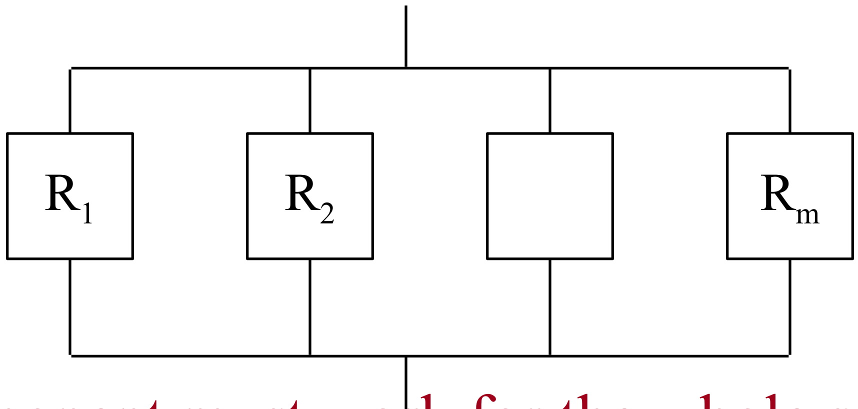


each component must work for the whole system to work

$$R_{whole} = \prod_{j=1}^{n} R_j$$

Reliability Models

Parallel System



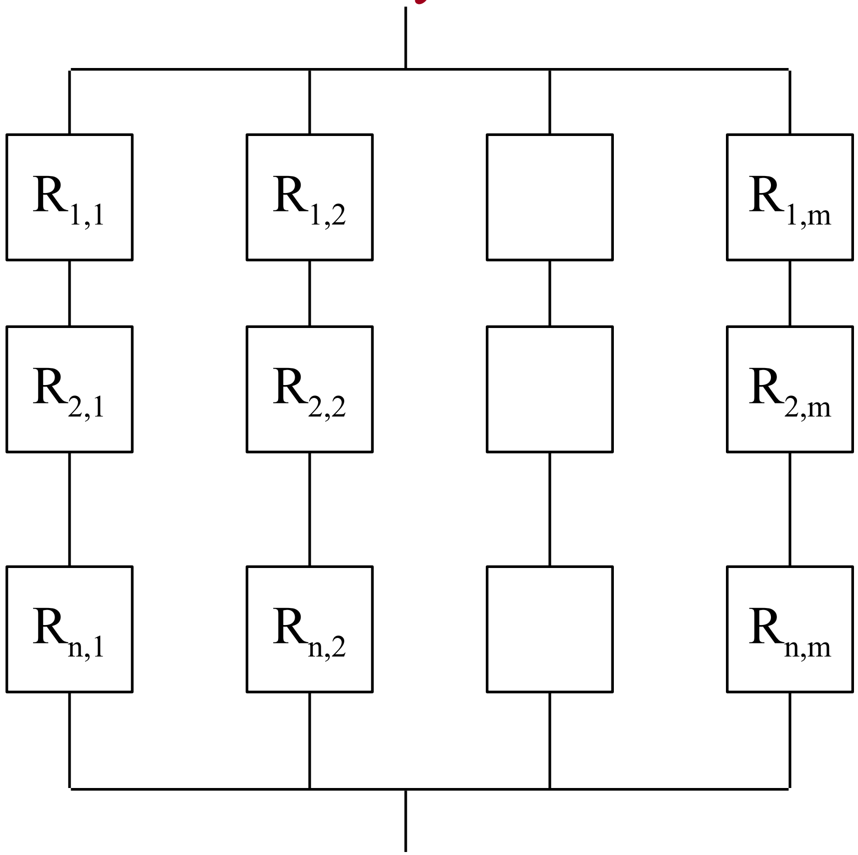
one component must <u>work</u> for the whole system to <u>work</u>

each component must <u>fail</u> for the whole system to <u>fail</u>

$$R_{whole} = 1 - \prod_{i=1}^{m} (1 - R_i)$$

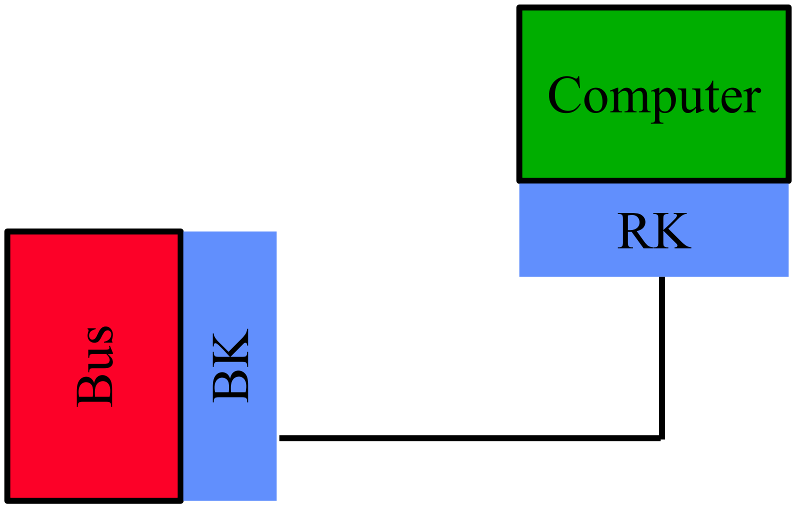
Reliability Models

Serial-Parallel System



$$R_{whole} = 1 - \prod_{j=1}^{m} \left(1 - \prod_{i=1}^{n} R_{i,j} \right)$$

Our Example



Fault Model::

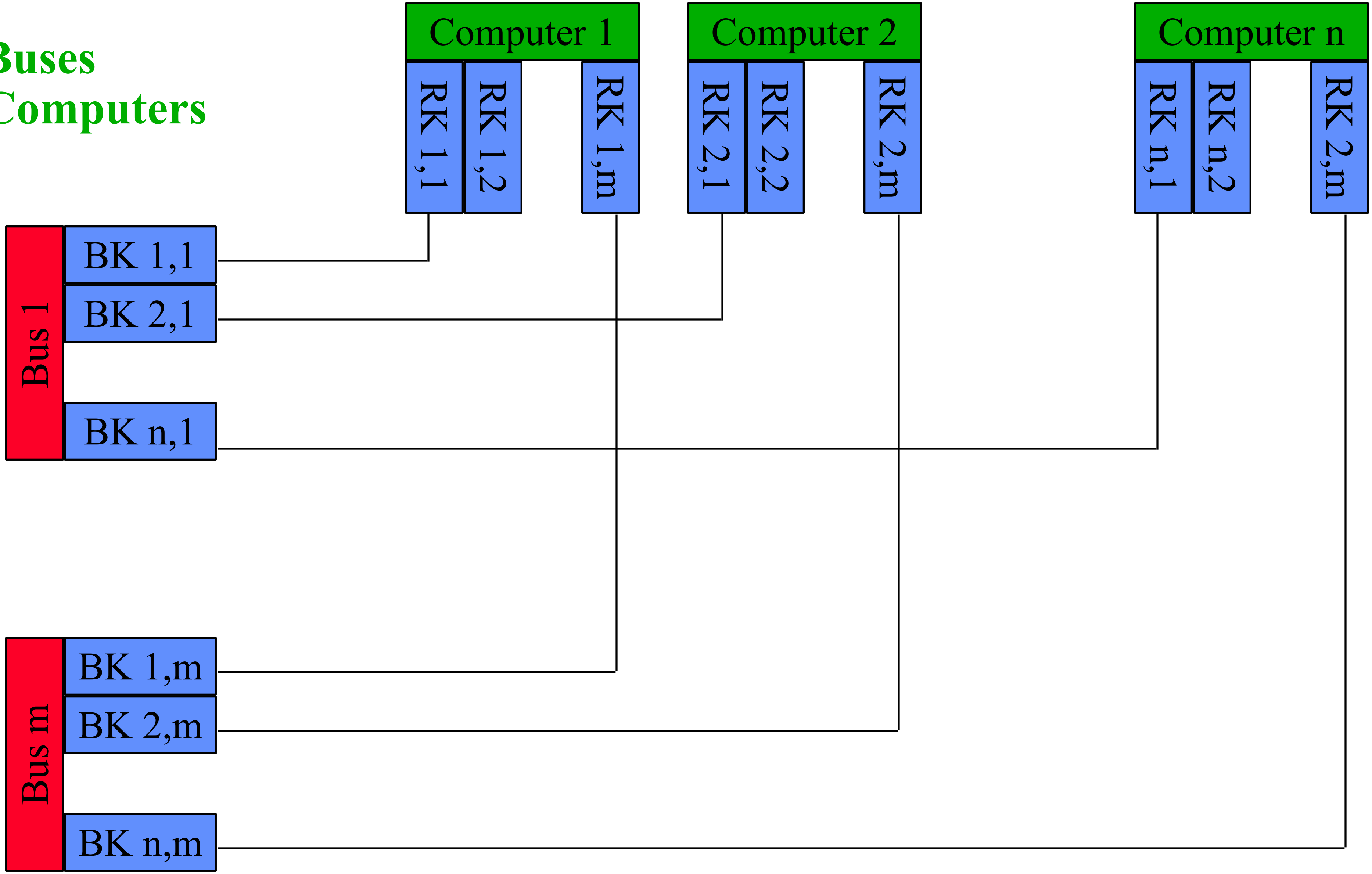
„Computer-Bus-Connector“

can fail such that Computer and/or Bus also fail

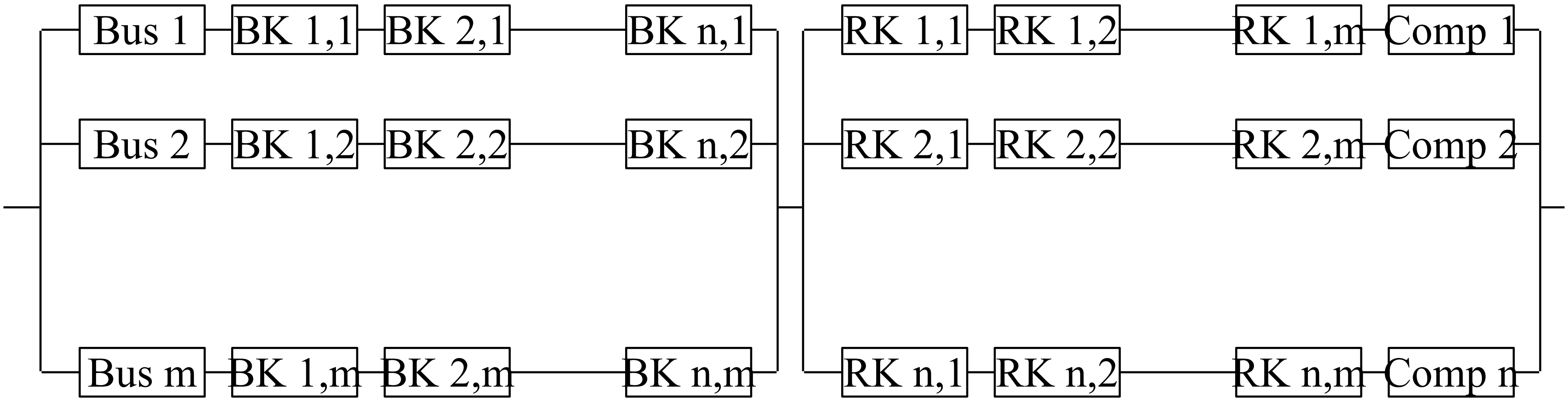
therefore we model:
conceptual separation of connector into

- RK: Computer-Connector, whose fault also breaks the Computer
- BK: Bus-Connector, ...

M Buses
N Computers



Model for m,n



$$R_{whole}(n,m)=\left(1-\left(1-R_{Bus}\cdot R_{BK}^{n}\right)^{m}\right)\cdot\left(1-\left(1-R_{Computer}\cdot R_{RK}^{m}\right)^{n}\right)$$

$$then:\ R_{RK}, R_{BK}<1:\ \lim_{n,m\to\infty} R(n,m)=??$$

Limits(mathematical) of Reliability, Variant 2

System built of Synapses (John von Neumann, 1956)

Computation and Fault Model:

Synapses deliver „0“ or „1”

Synapses deliver with R > 0,5:

- with probability R correct result
- with (1-R) wrong result

Then we can build systems that deliver correct result for any (arbitrary high) probability R

Report here: cum grano salis!!

Two Army Problem (Coordinated Attack)

- p,q processes
  communicate using messages
  messages can get lost
  no upper time for message delivery known
  do not crash, do not cheat

- p,q to agree on action (e.g. attack, retreat, ...)

- how many messages needed ?

- first mentioned: Jim Gray 1978

Two Army Problem (Coordinated Attack)

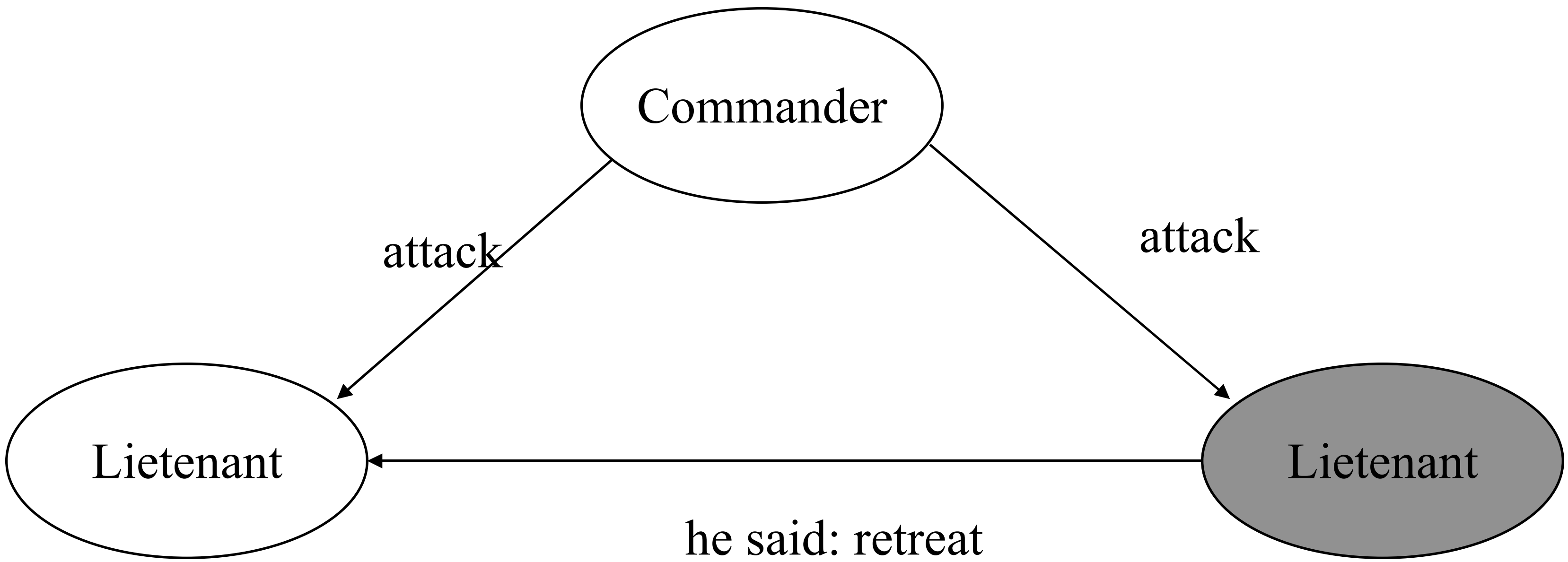
- Result:
  there is no protocol with finite messages
- Prove:
  by contradiction
  assume there are finites protocols ($m_{p\text{-->} q}$, $m_{q \text{-->} p}$)*
  choose the shortest protocol MP,
  last message MX: $\underline{m}_{p \text{-->} q}$ or $\underline{m}_{q \text{-->} p}$
  MX can get lost
  => must not be relied upon => can be omitted
  => MP not the shortest protocol.
  => no finite protocol

Byzantine Agreement

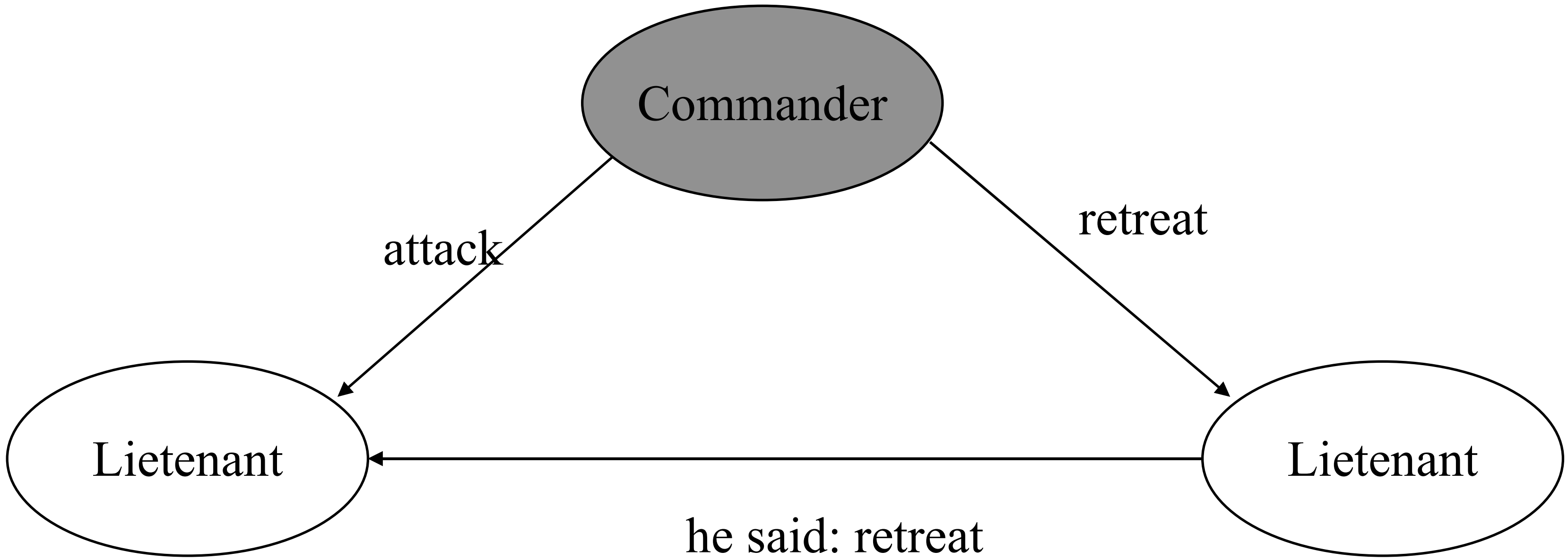
- n processes, f traitors, n-f loyals
  communicate by reliable and timely messages
  (synchronous messages)
  traitors lye, also cheat on forwarding messages
  try to confuse loyals

- goal:
  loyals try to agree on action (attack, retreat)
  more specific:
  one process is commander
  if commander is loyal and gives an order,
  loyals follow the order
  otherwise loyals agree on arbitrary action

3 Processes: 1 traitor, 2 loyals

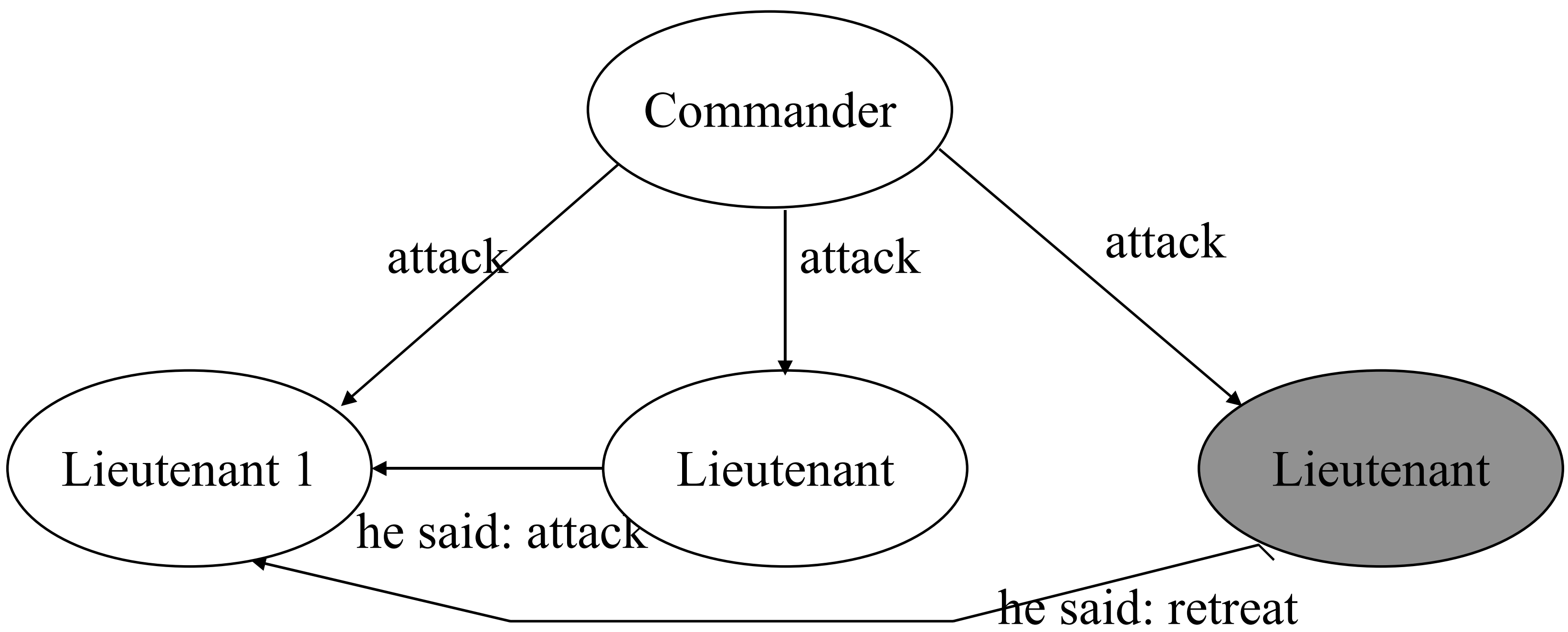


3 Processes: 1 traitor, 2 loyals

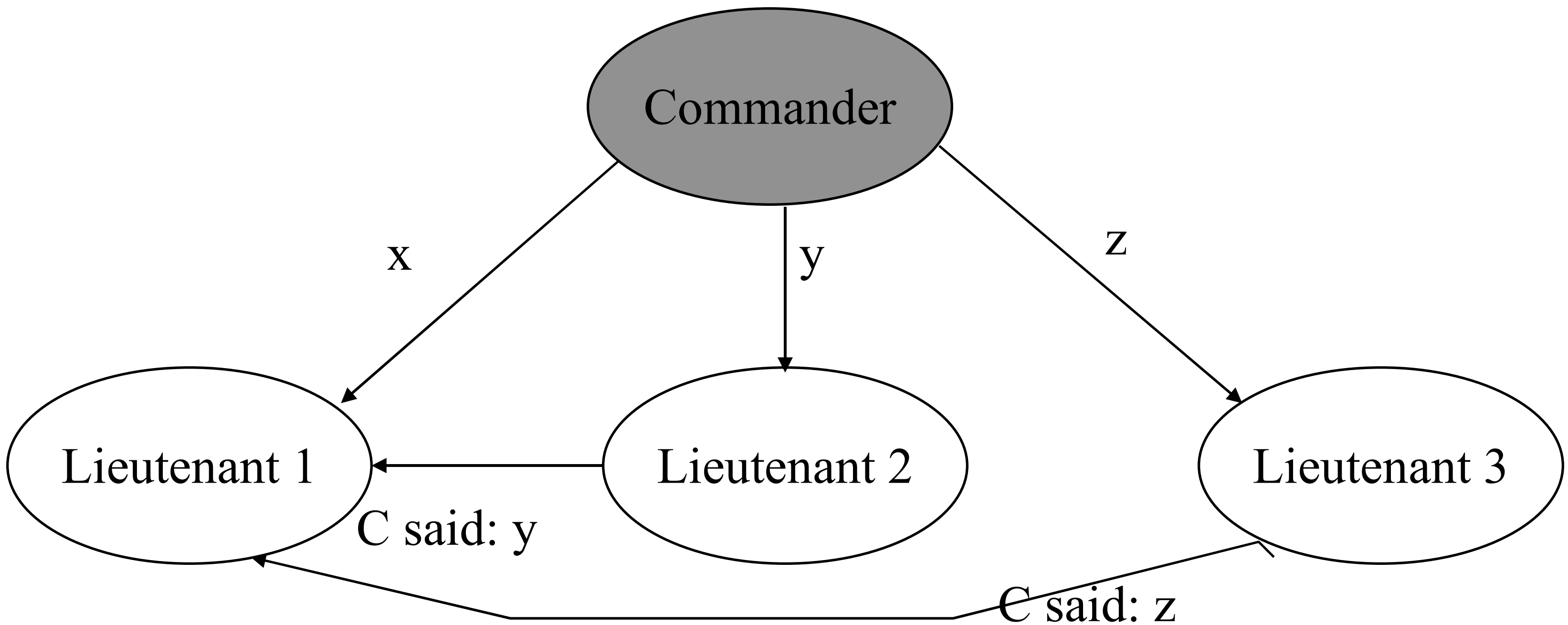


- 3 processes not sufficient to tolerate 1 traitor

4 Processes


Commander
attack
attack
attack
Lieutenant 1
Lieutenant
Lieutenant
he said: attack
he said: retreat

4 Processes



- all lieutenant receice x,y,z
- can decide
- General result:
  3 f + 1 processes needed to tolerate f traitors

To take away

modeling is very powerful

extreme care needed to do it correctly