Today's Topics - Coordination and Agreement

Chapter 12.

- Distributed Mutual Exclusion. 12.2
- Consensus 12.5

figures to insert fig. 12.2,12.3

Distributed Mutual Exclusion

- As in operating systems we some want mutual exclusion: that is we don't want more than one process accessing a resource at a time.
- In operating systems we solved the problem by using either using semaphores (`P` and `V` or by using atomic actions.)
- In a distributed system we want to be sure that we can access a resource and that nobody else is accessing the resource.
- A critical section is a piece of code where we want mutual exclusion.

Requirements for Mutex Algorithms

Safety At most one process may execute in the critical section at a time.

liveness Requests to enter and exit the critical section eventually succeed.

The liveness condition implies freedom from both deadlock and starvation. A *deadlock* would involve two or more of the processes becoming stuck indefinitely. *Starvation* is indefinite postponement of entry for a process that has requested it.

Further Requirements

→ **ordering** Access is granted in the happened before relation.

This is desirable so that process can coordinate their actions. A process might be waiting for access and communicating with other processes.

It is hard to do this when the message delays are unbounded. Later we will see an algorithm based on Lamport timestamps.

Performance criteria

bandwidth The bandwidth consumed, which is proportional to the number of messages sent in each entry or exit to the C.S.

client delay The client delay incurred by a process entering or exiting the C.S.

throughput The algorithm's effect upon the *throughput* of the system.

The Central server Algorithm

The central server algorithm can be seen as a *token* based algorithm. The system maintains one token and make sure that only one process at a time gets that token. A process has to not enter the C.S. if it doesn't have a token. Fig. 12.2

- A process request to enter the C.S. by asking the central server.
- The central server only grants access to one person at a time.
- The central server maintains a queue of requests and grants them in the order that people sent them.
- Main disadvantage: Single point of failure.
- Main advantage: Lower overhead in communication.

Token ring based algorithm

- Arrange them in a logical ring.
- Pass the token around.
- If you get the token and you don't want to enter the C.S. pass the token on otherwise keep hold of it.
- Disadvantage: Maximum message delay equal size of the ring minus 1.

Insert fig. 12.3

Lamport Timestamps

- Remember that Lamport timestamps give a total order that everybody can agree on.
- Basic idea of *Ricart and Agrawala's* algorithm. When ever somebody wants to enter the C.S. it multicasts to everybody a message saying I want to enter.
- When it receives Ok messages from everybody else then it enters.
- If the process wants to enter the C.S. and receives a request it compares timestamps and waits if the received message has an earlier timestamp. (If timestamps are identical then use process i.d. as a tiebreaker). Main disadvantage large communication overhead.

Maekawa's Voting Algorithm

- Maekawa's algorithm make is possible for a process to enter the critical section by obtaining permission from only a subset of the other processes.
- This is done by associating a voting set V_i with each process p_i. The sets V_i are chosen s.t.
  - $p_i \in V_i$
  - $V_i \cap V_j \neq \emptyset$
  - $|V_i| = K$ each voting set is of the same size.
  - Each process p_j is contained in M of the voting set V_i.

Maekawa's Voting Algorithm

- To obtain entry into the critical section a processes sends a `request` message to all other $K - 1$ members of V_i.
- When it receives the replies it can enter.
- When it has finished it sends a `release` message.
- If a process gets a vote request if it is not in the Critical section and it has not received a previous vote request it replies.
- Otherwise a process might of received a vote request but no `release` message. In that case it queues the request and waits until the `release` message comes.

The correctness proof needs the overlapping voting sets.

Consensus

- How do a group of processors come to a decision?
- Example suppose a number of generals want to attack a target. They know that they will only succeed if the all attack. If anybody backs out then it is going to be a defeat.
- The example becomes more complicated if one of the generals becomes a traitor and starts to try and confuse the other generals. By saying yes I'm going to attack to one and no I'm not to another.
- How do we reach consensus when there are Byzantine failures? It depends on if the communication is synchronous or asynchronous.

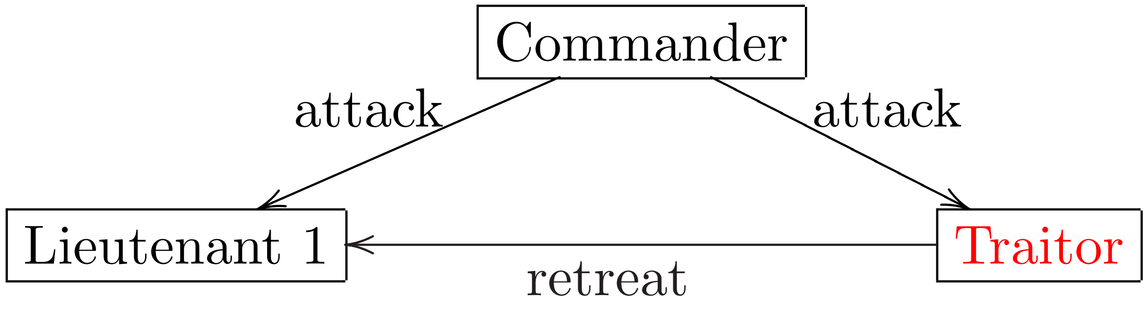
Byzantine Generals in a synchronous system

Problem:

- A number of processes.
- Private synchronous channels between them.
- Process try and reach consensus or agree on a value.
- Goal given a number of faulty processes is it possible to distinguish between correct communication and faulty communication?

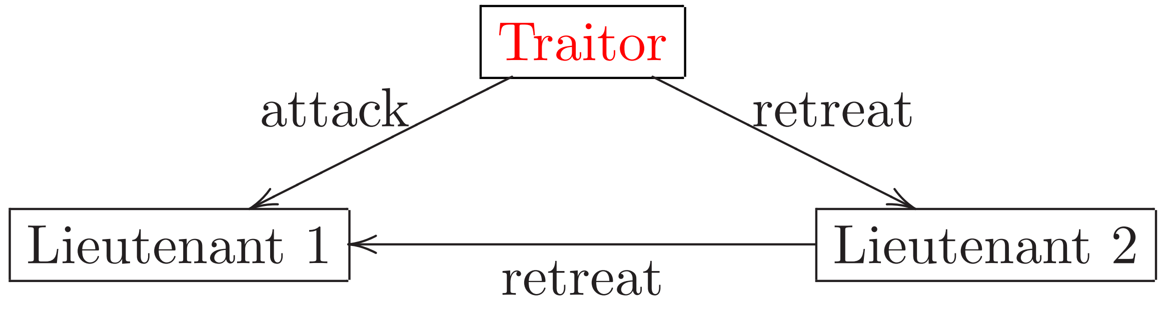
Impossibility with three processes

Situation a commander with two lieutenants. The commander is trying to send an attack order to both. If one of the lieutenants is treacherous then:



Impossibility with three processes

If the commander is treacherous then:



Lieutenant 1 does not have anyway of distinguishing between the first and second situations. So there is no solution to the Byzantine general problem with 2 ok processes and 1 traitor.

Extending the result

- You can show that there is no solution to the problem if N the number of processes and f the number of faulty processes satisfies

$$N \leq 3f$$

- You do this by taking a supposed solution with a more than a third of the processes faulty and then turn this into a solution for 1 faulty and 2 correctly working generals, by getting the three generals to simulate the solution for then $N \leq 3f$ situation, by passing more messages.

Solution where $N > 3f$

Instead of presenting the general algorithm we will present the solution with 1 faulty process and 3 correct processes.

The solution uses a majority function which has the property that

$$\text{majority}(x, x, y) = \text{majority}(y, x, x) = \text{majority}(x, y, x) = x$$

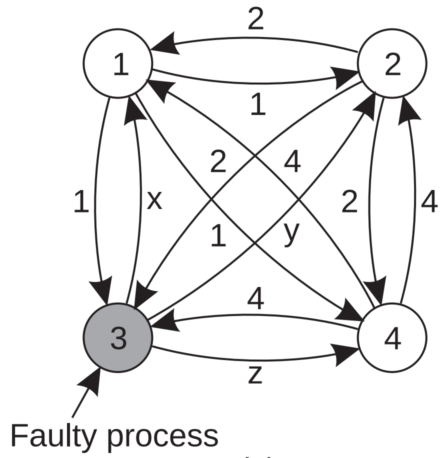
The protocol has two rounds in the general version there a number of rounds.

Solution with one Faulty process

Two rounds:

- In the first round the commander sends a value to each of the lieutenants.
- In the second round each of the lieutenants sends the value it received to its peers.

A lieutenant receives a value from the commander, plus $N - 2$ values from its peers. Each lieutenant and the commander uses the majority function to compute the correct value.



(a)

```
1  Got(1, 2, x, 4)
2  Got(1, 2, y, 4)
3  Got(1, 2, 3, 4)
4  Got(1, 2, z, 4)
```

(b)

1 Got	2 Got	4 Got
(1, 2, y, 4)	(1, 2, x, 4)	(1, 2, x, 4)
(a, b, c, d)	(e, f, g, h)	(1, 2, y, 4)
(1, 2, z, 4)	(1, 2, z, 4)	(i, j, k, l)

(c)

Impossibility in asynchronous system

- The discussion so far has relied on message passing being synchronous.
- Messages pass in rounds.
- In an asynchronous system you can't distinguish between a late message and a faulty process.
- You can it is impossible to solve the Byzantine general problem in an asynchronous system.