A Distributed Coordination Problem

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https://www.youtube.com/watch?app=desktop&v=IP-rGJKSZ3s

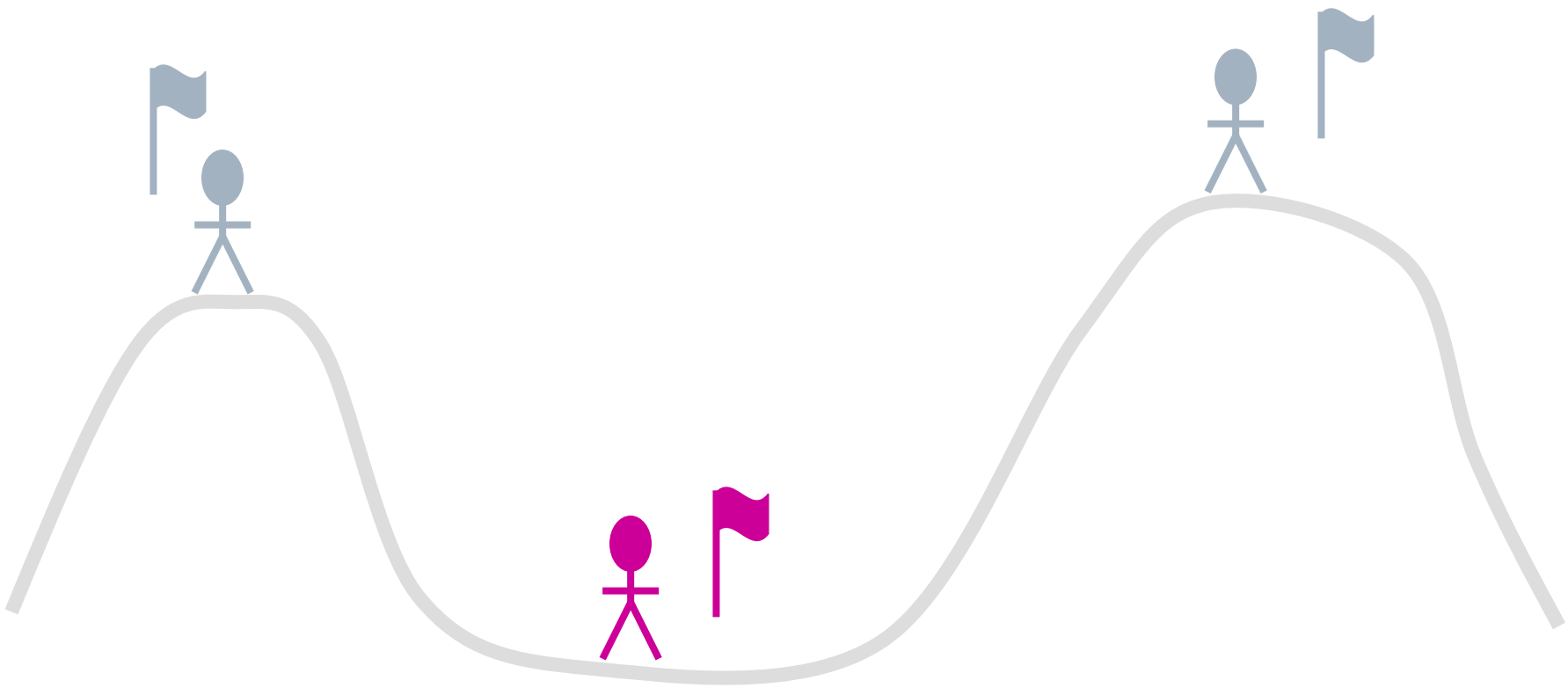
It is impossible for two distributed processes communicating via an unreliable message system to reach consensus

Two Generals' Problem

Two armies are camped on separate hills surrounding a valley in which the enemy army is encamped.

The enemy can vanquish each general separately, but if both generals attack at the same time, they can vanquish the enemy.

Two Generals' Problem



due to Jim Gray, 1978

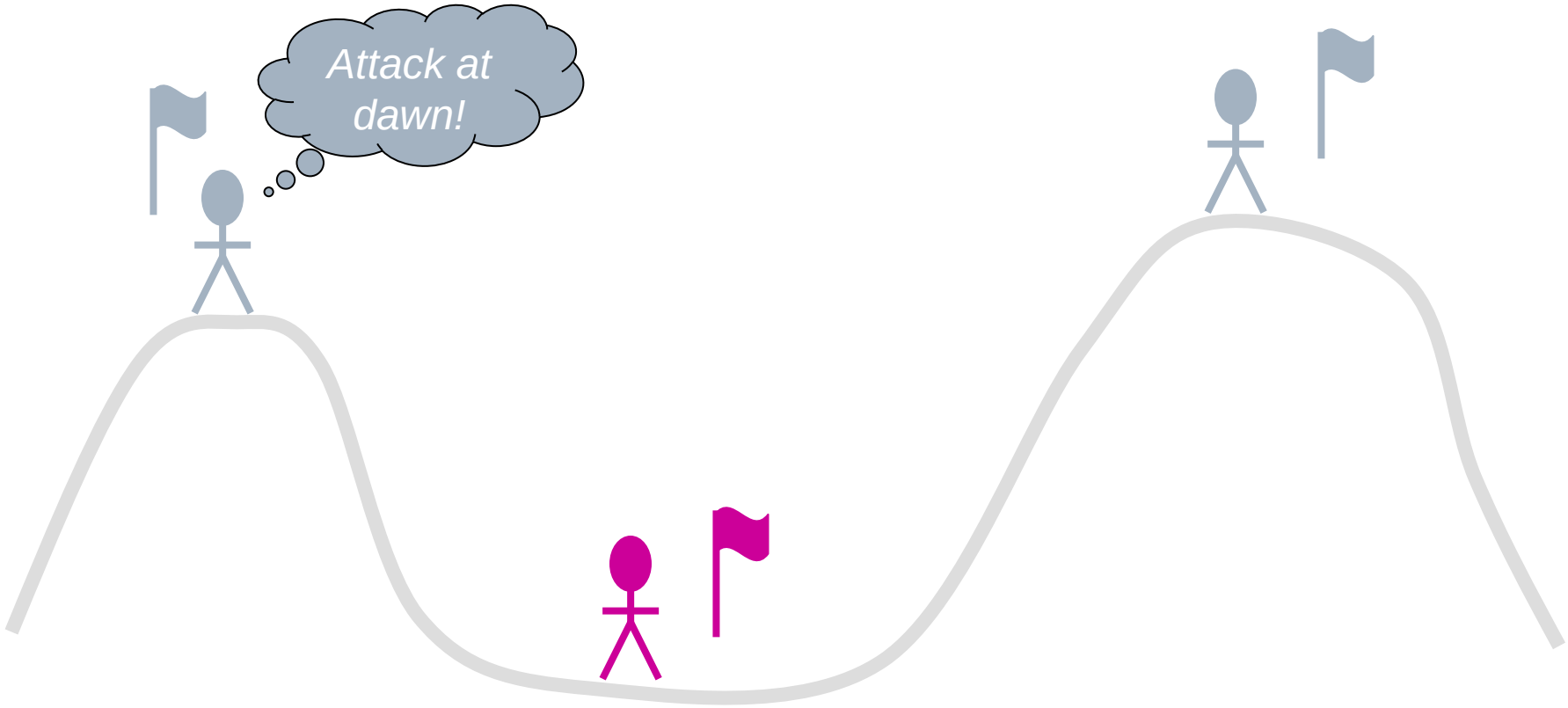
Two Generals' Problem

The two generals must communicate with each other to agree upon whether or not to attack at dawn.

Each general must know that the other general knows that they have agreed to the attack plan.

There should be a shared certainty for both generals to attack.

Two Generals' Problem



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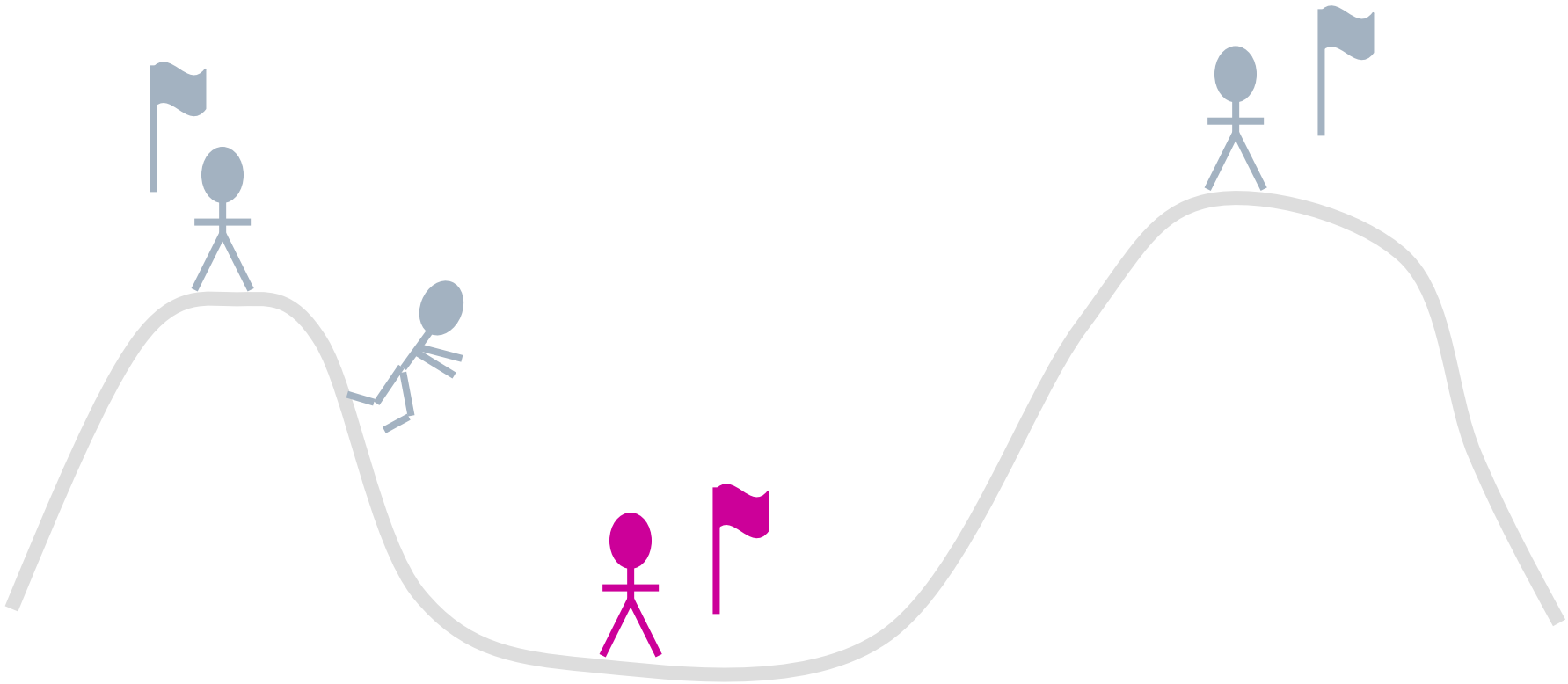

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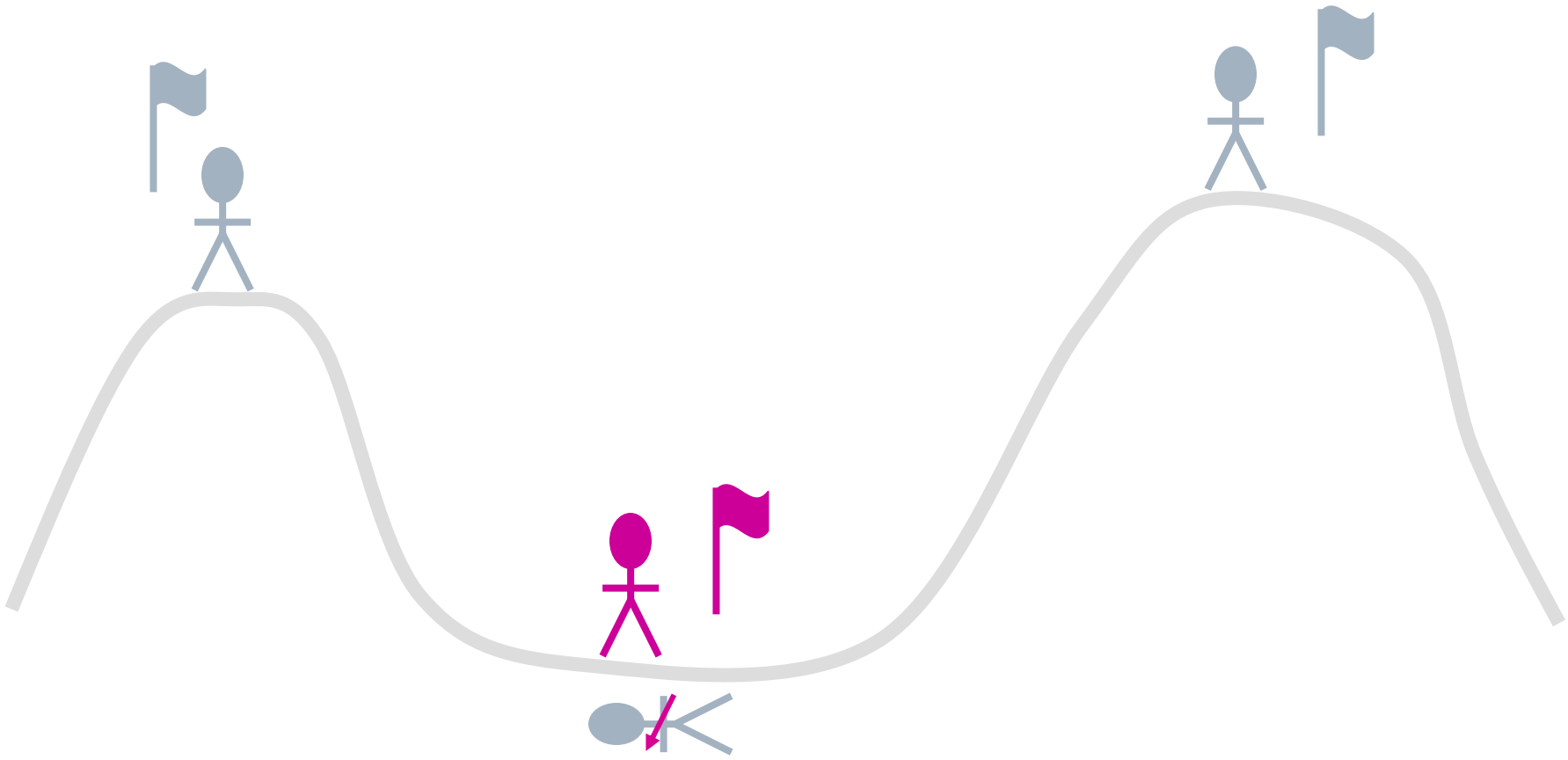

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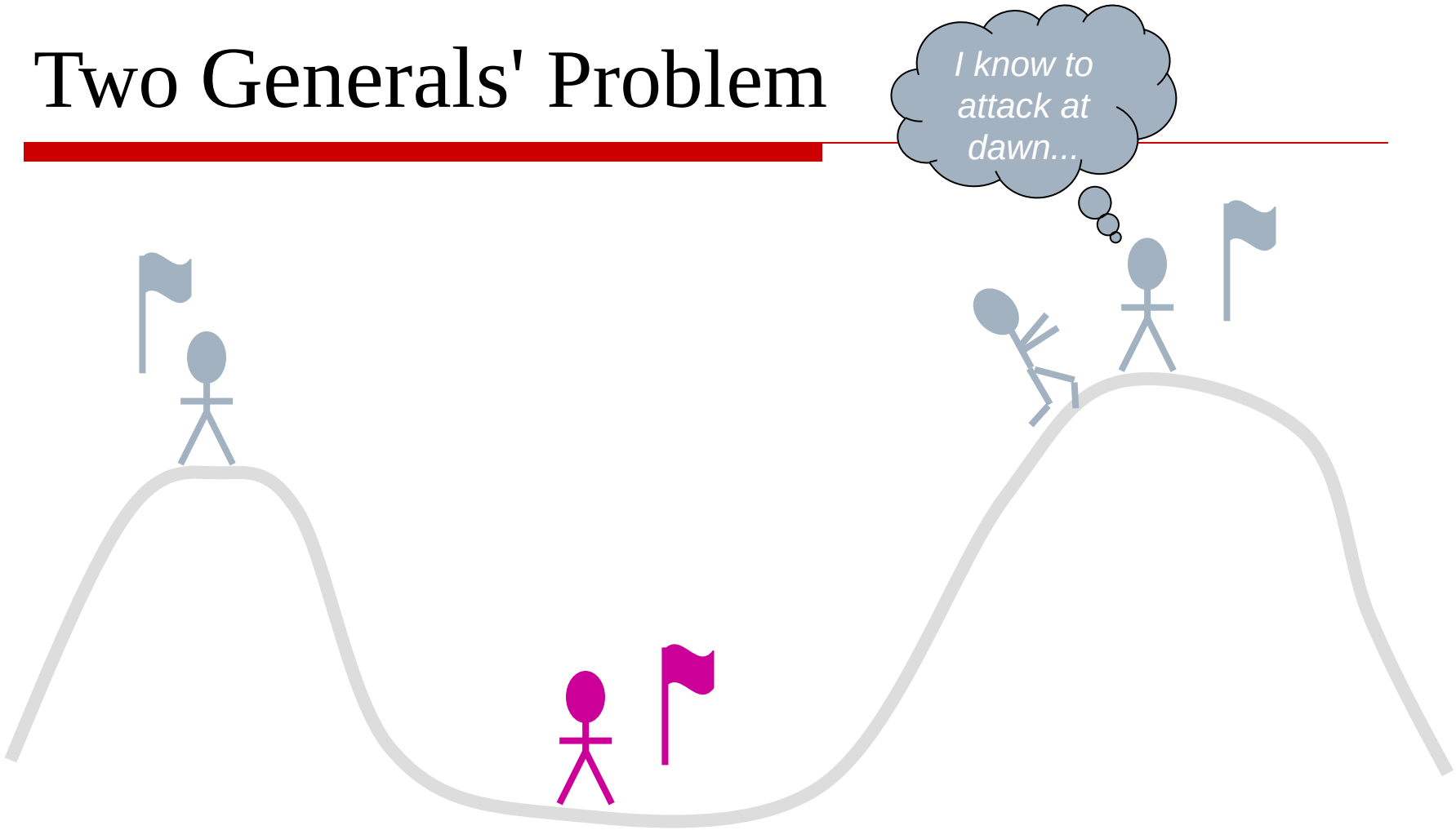

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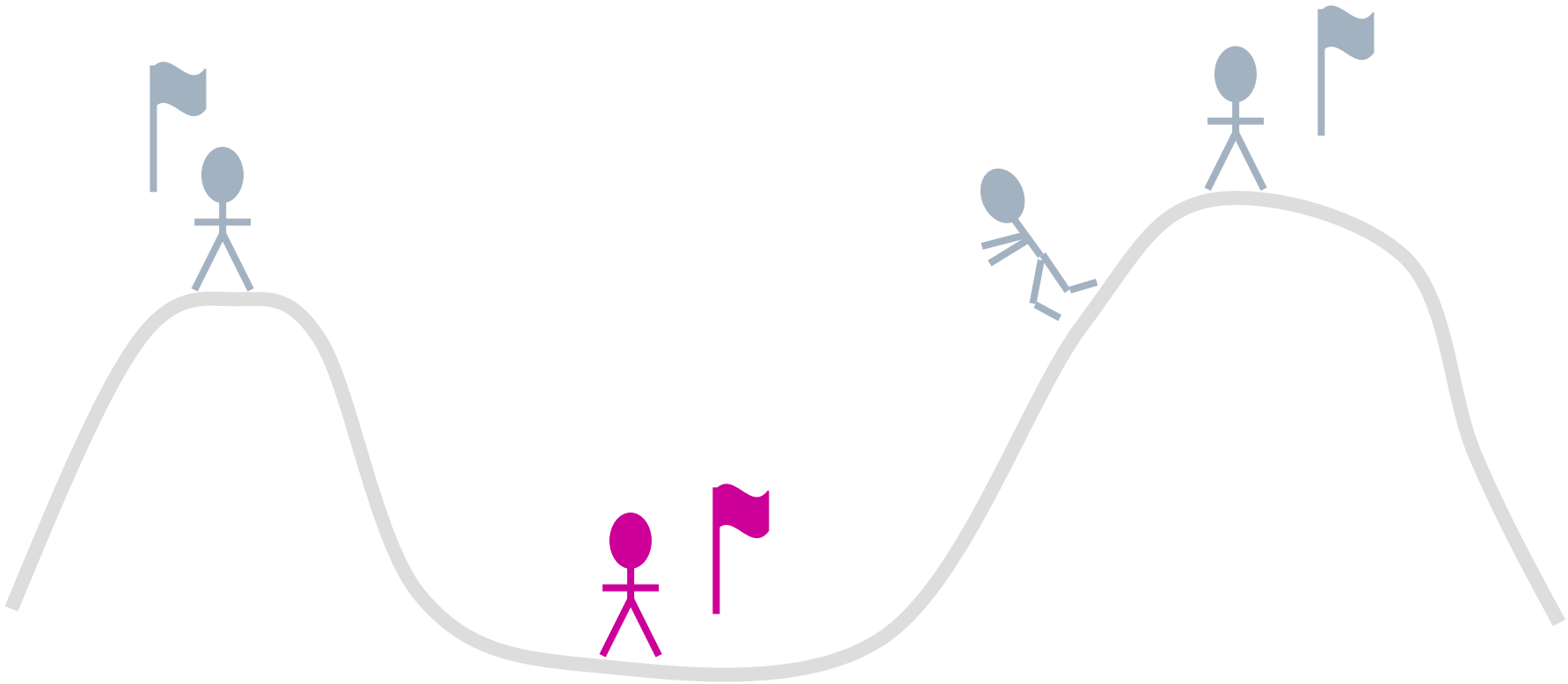
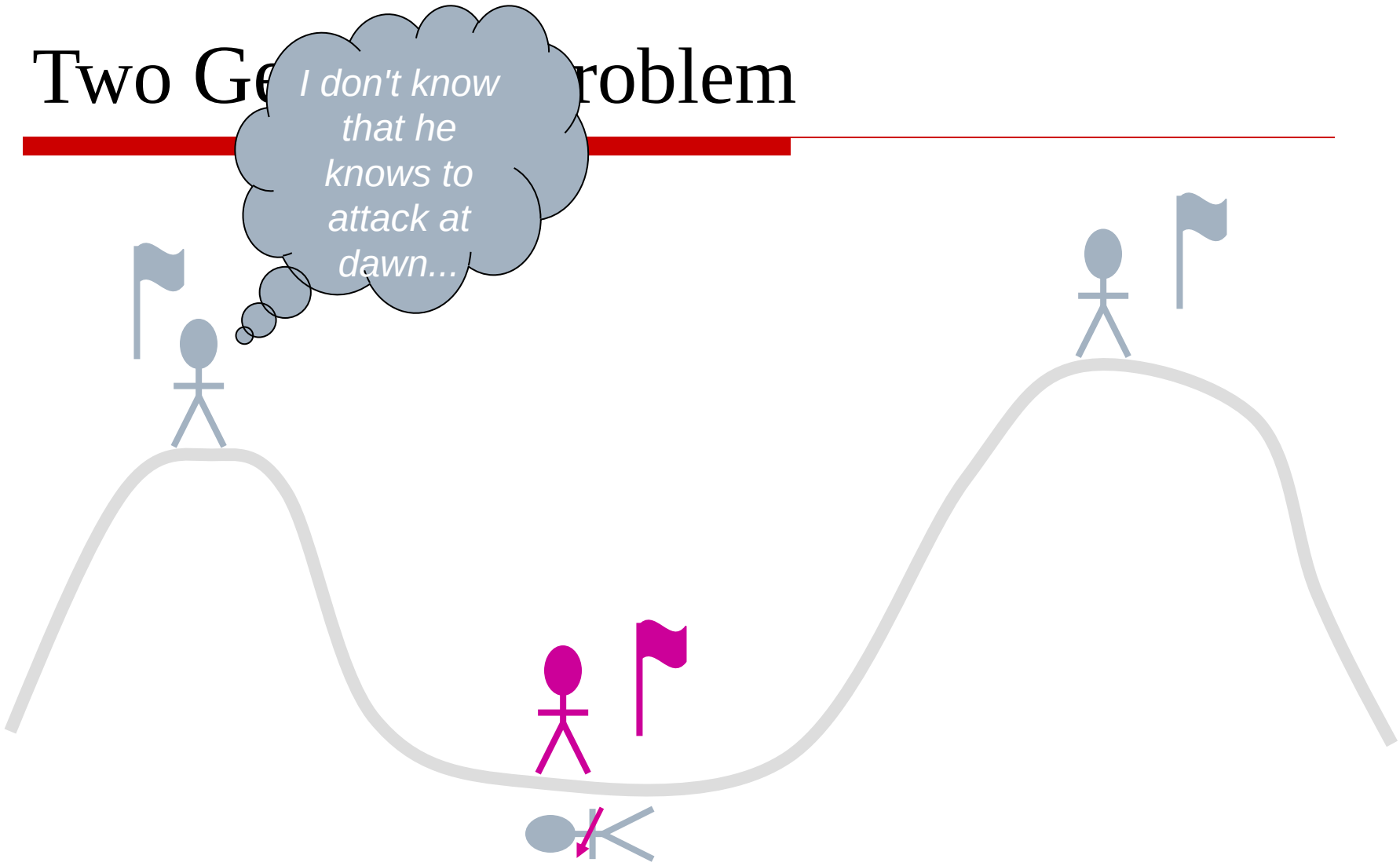


Two Ge roblem



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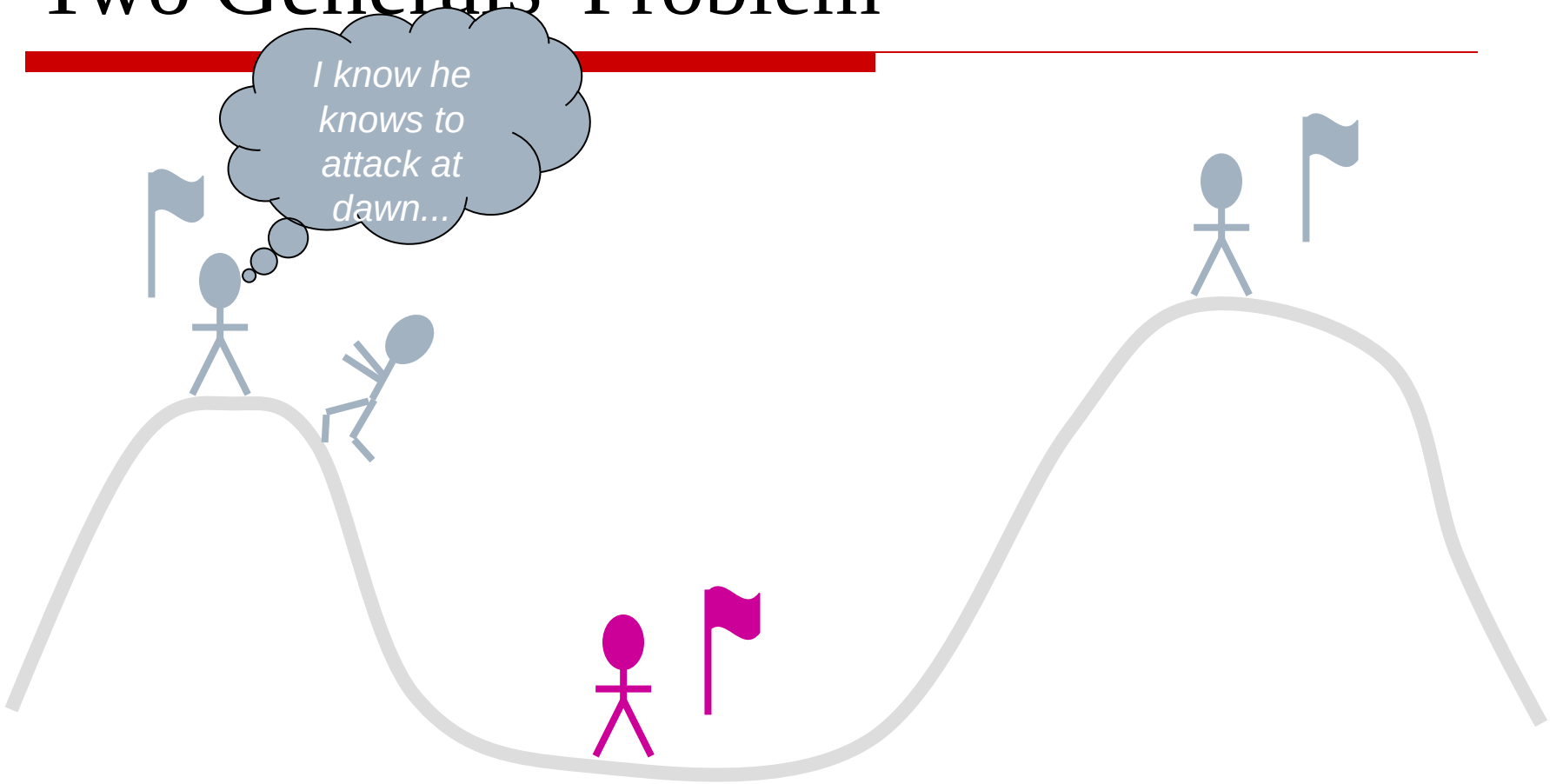

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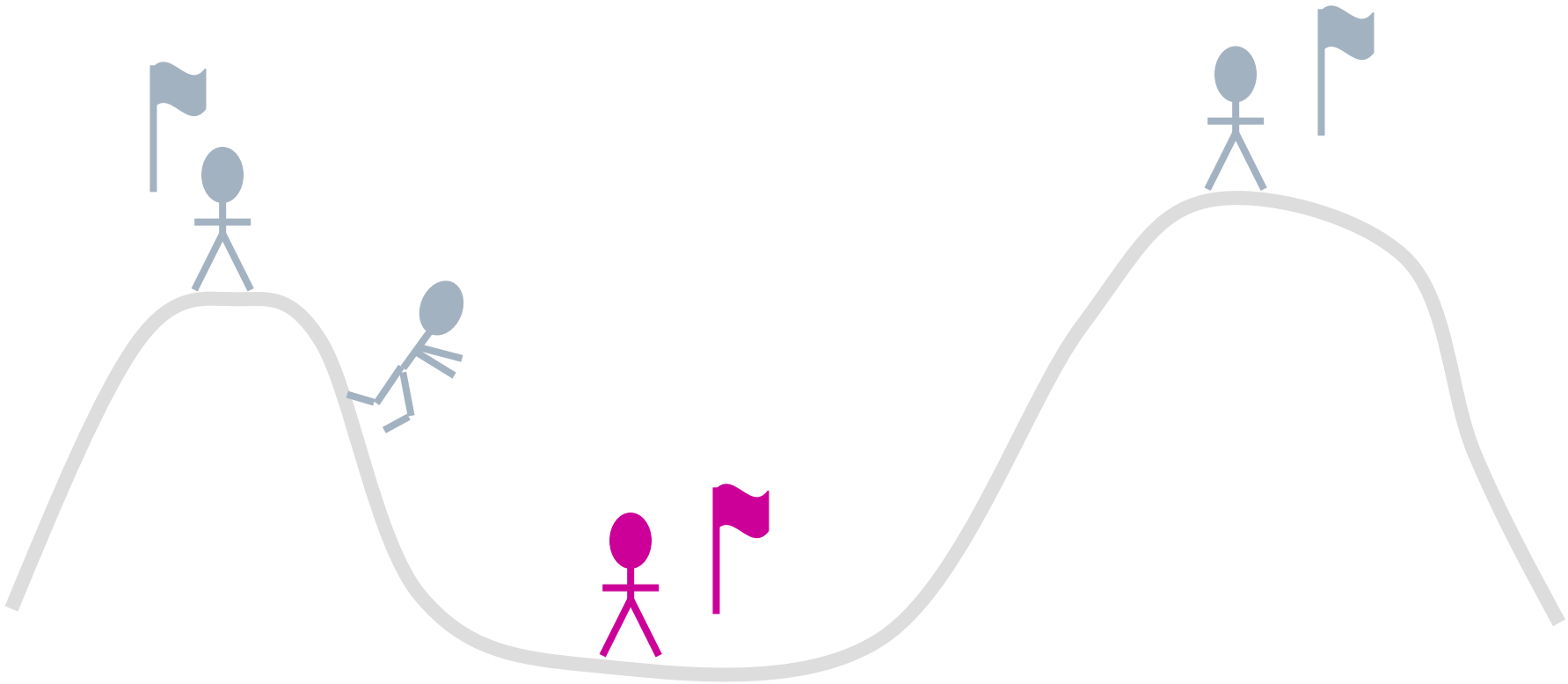

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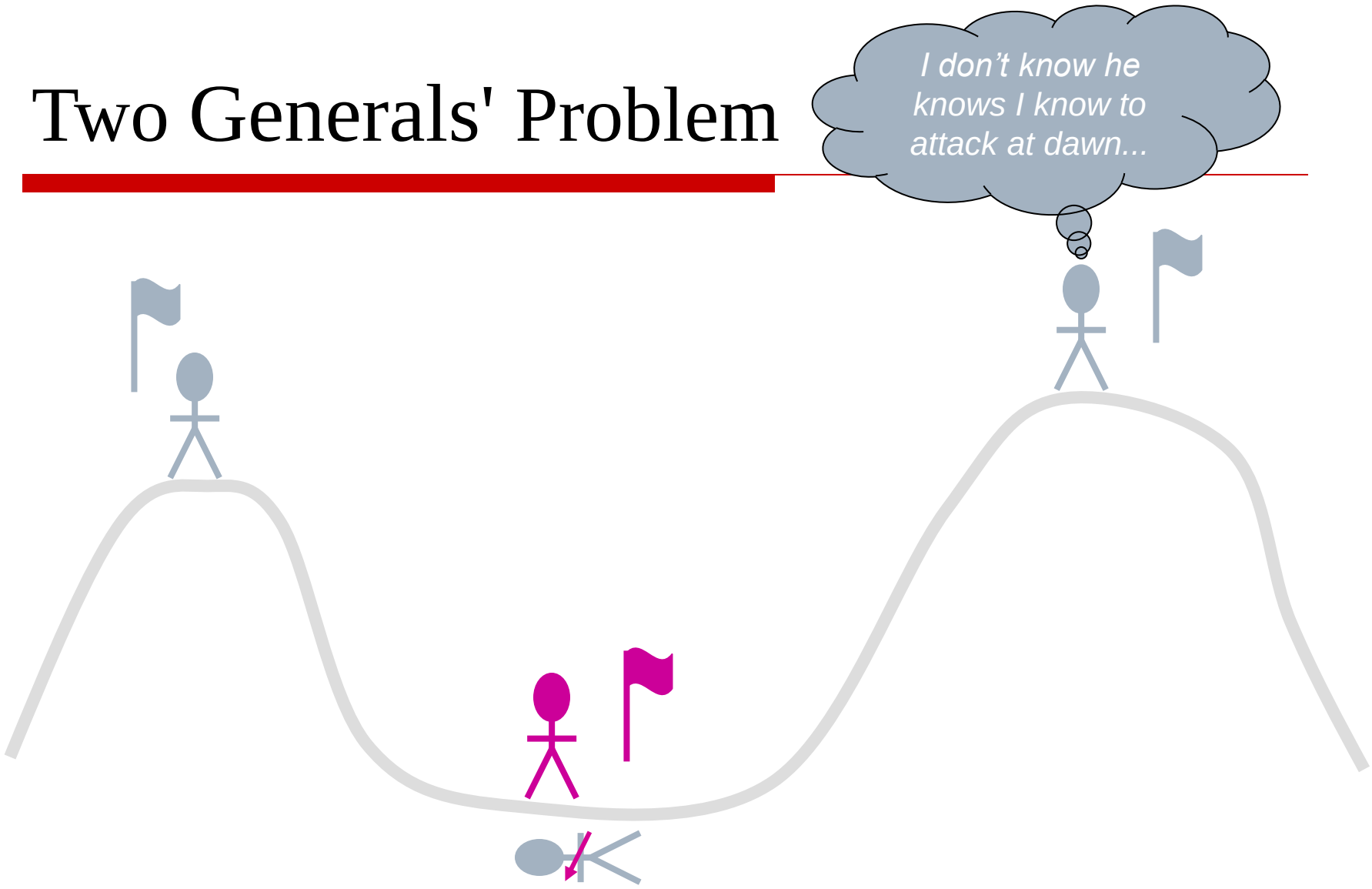
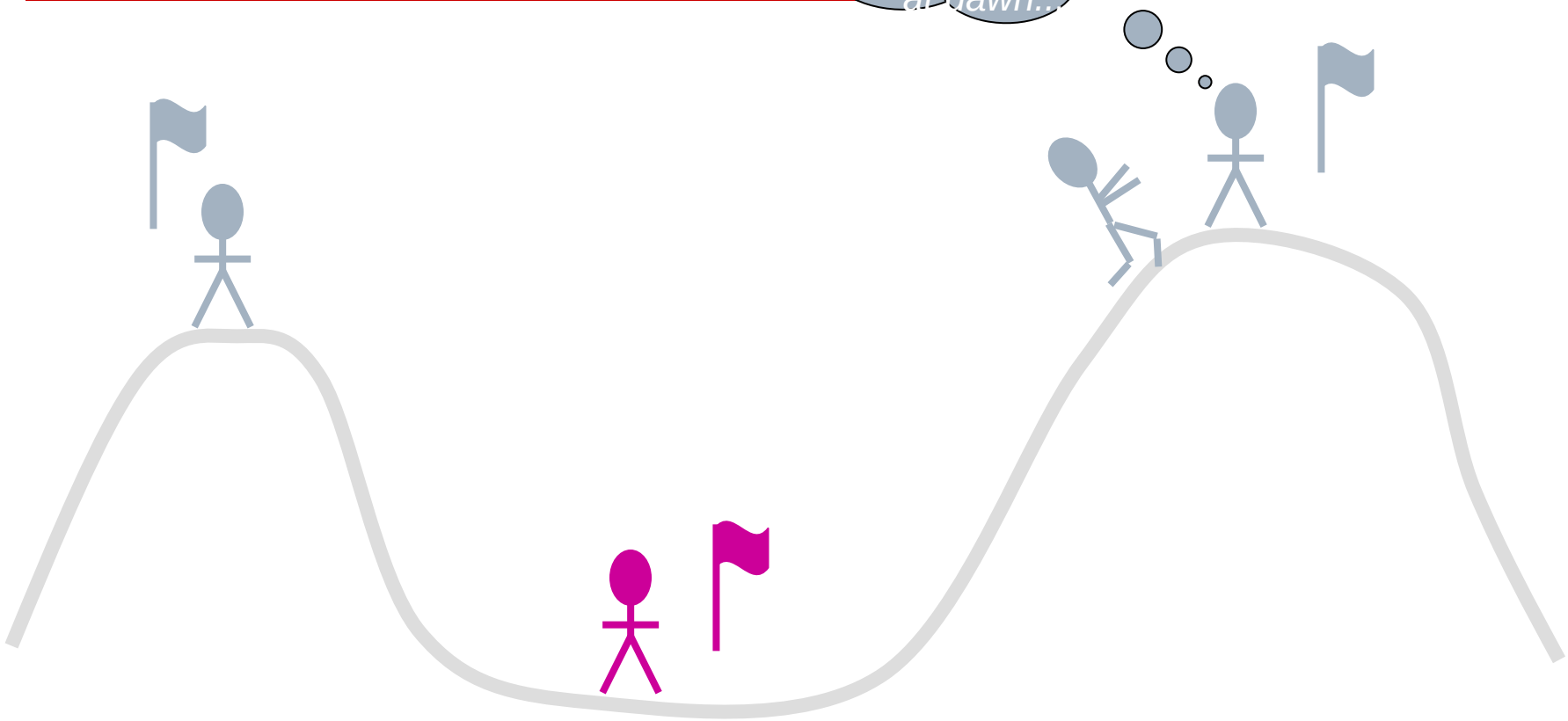


Two Generals' Probl



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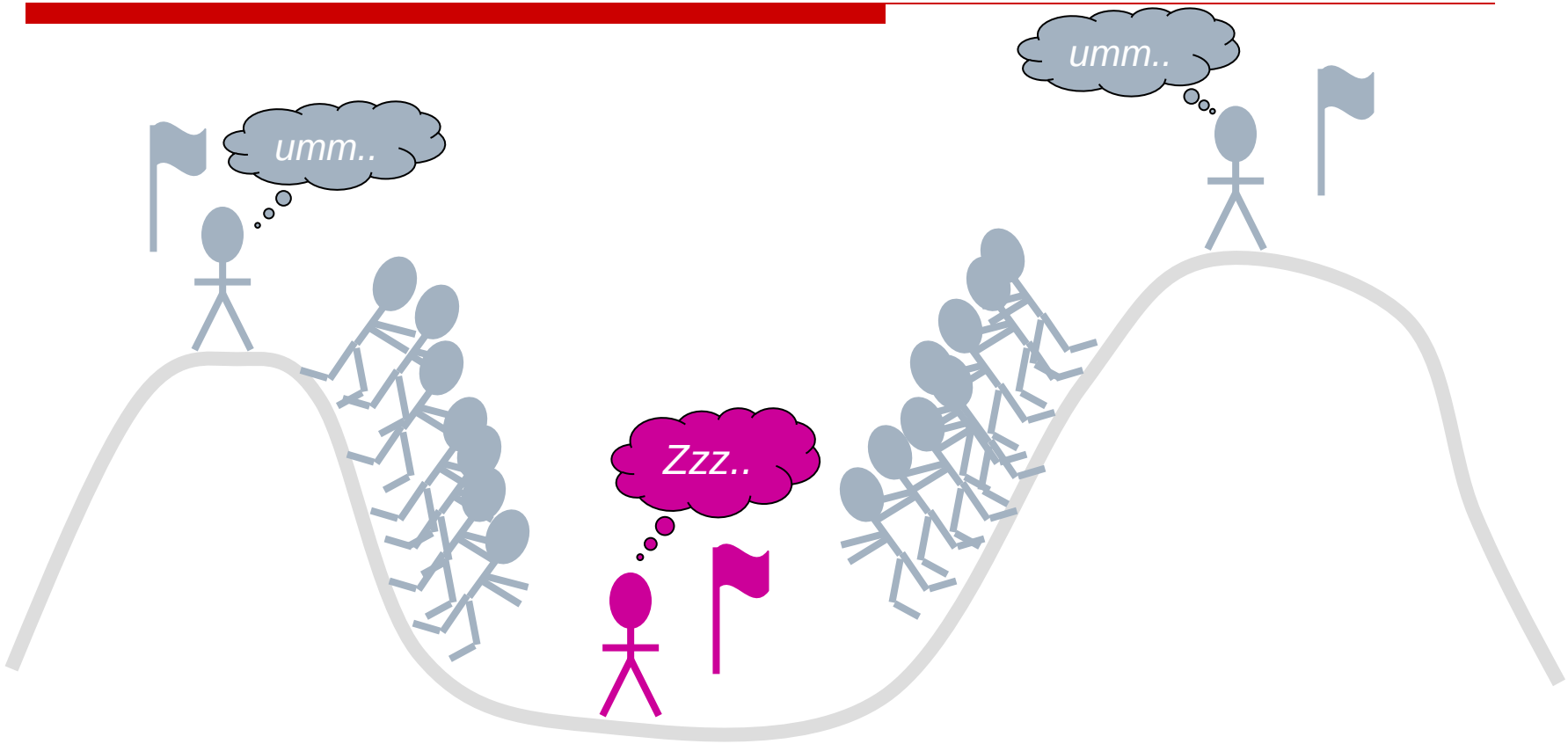
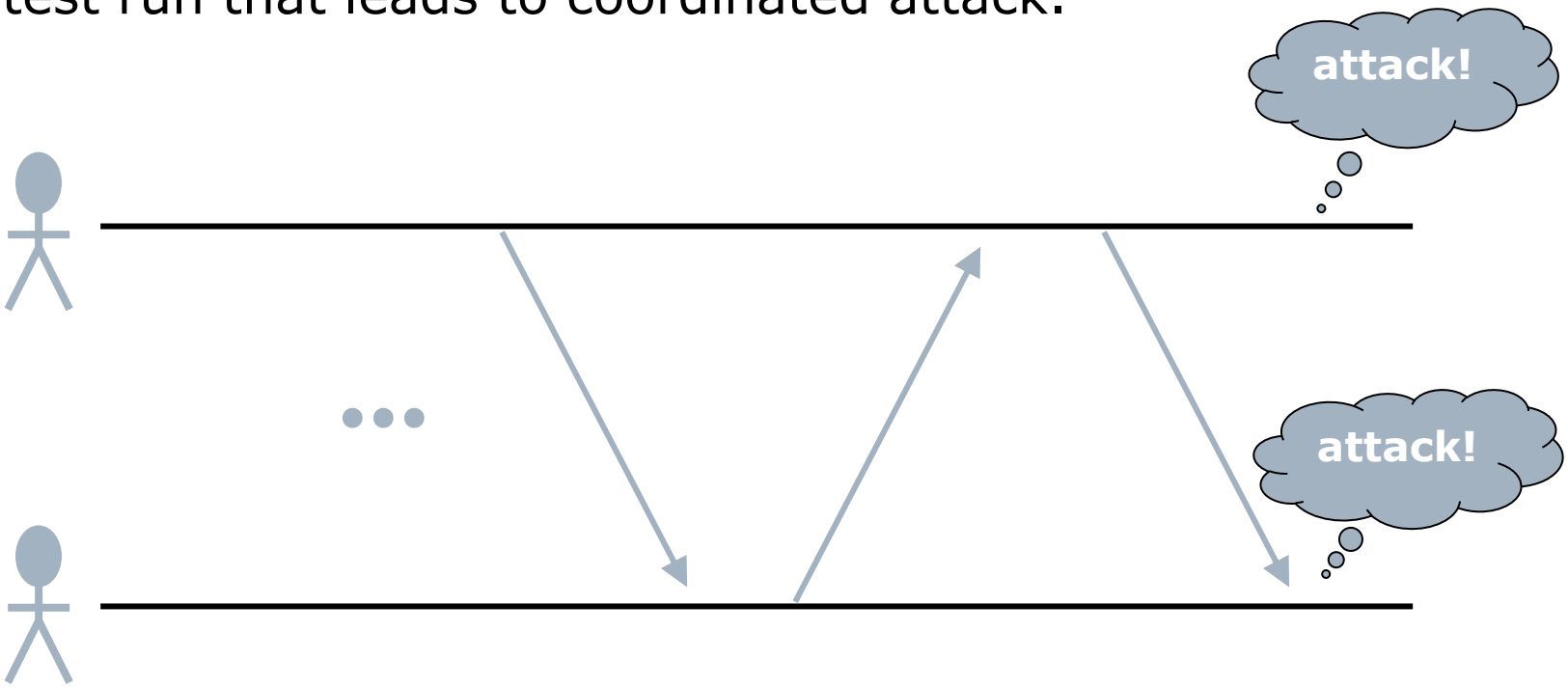


No Finite Protocol: Proof

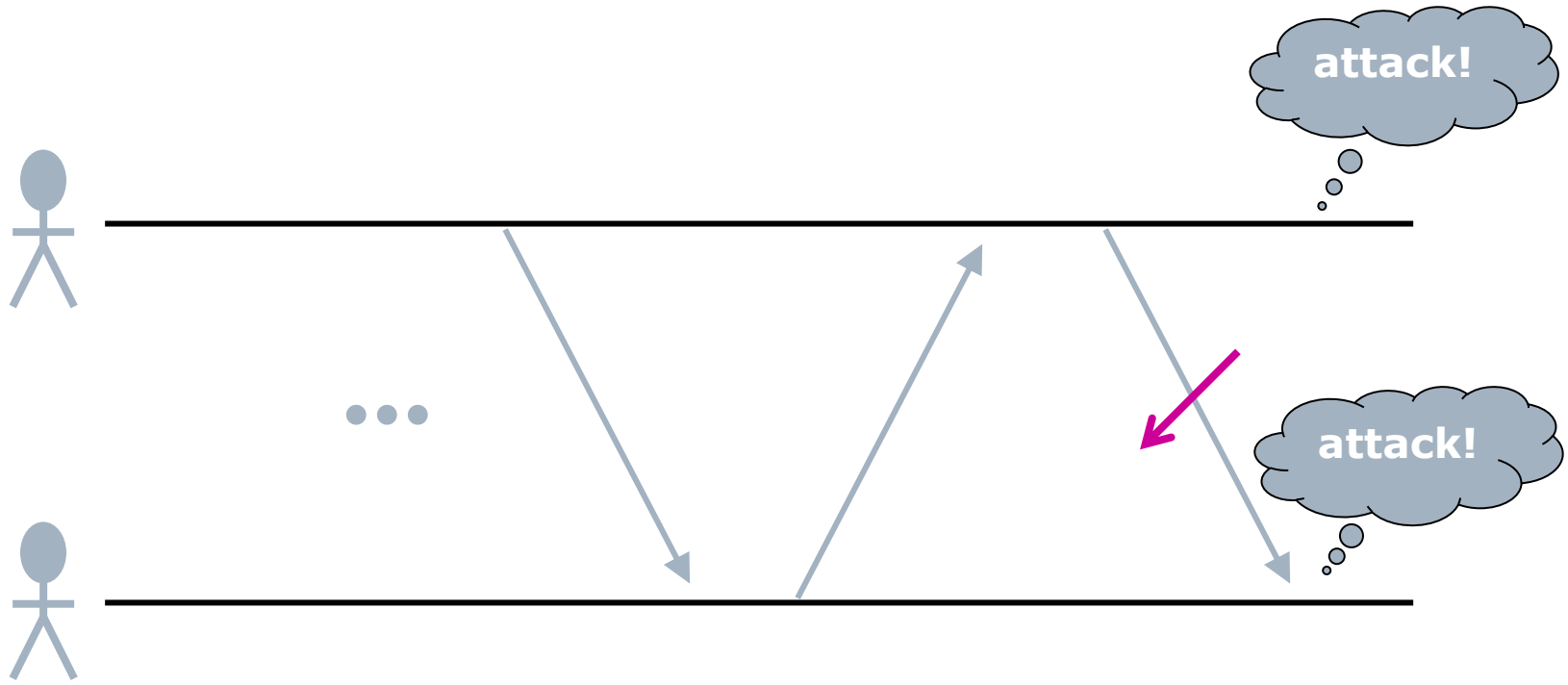
Assume a protocol P exists and consider the shortest run that leads to coordinated attack.



No Finite Protocol: Proof

- Suppose the last messenger in P gets lost.

No Finite Protocol: Proof

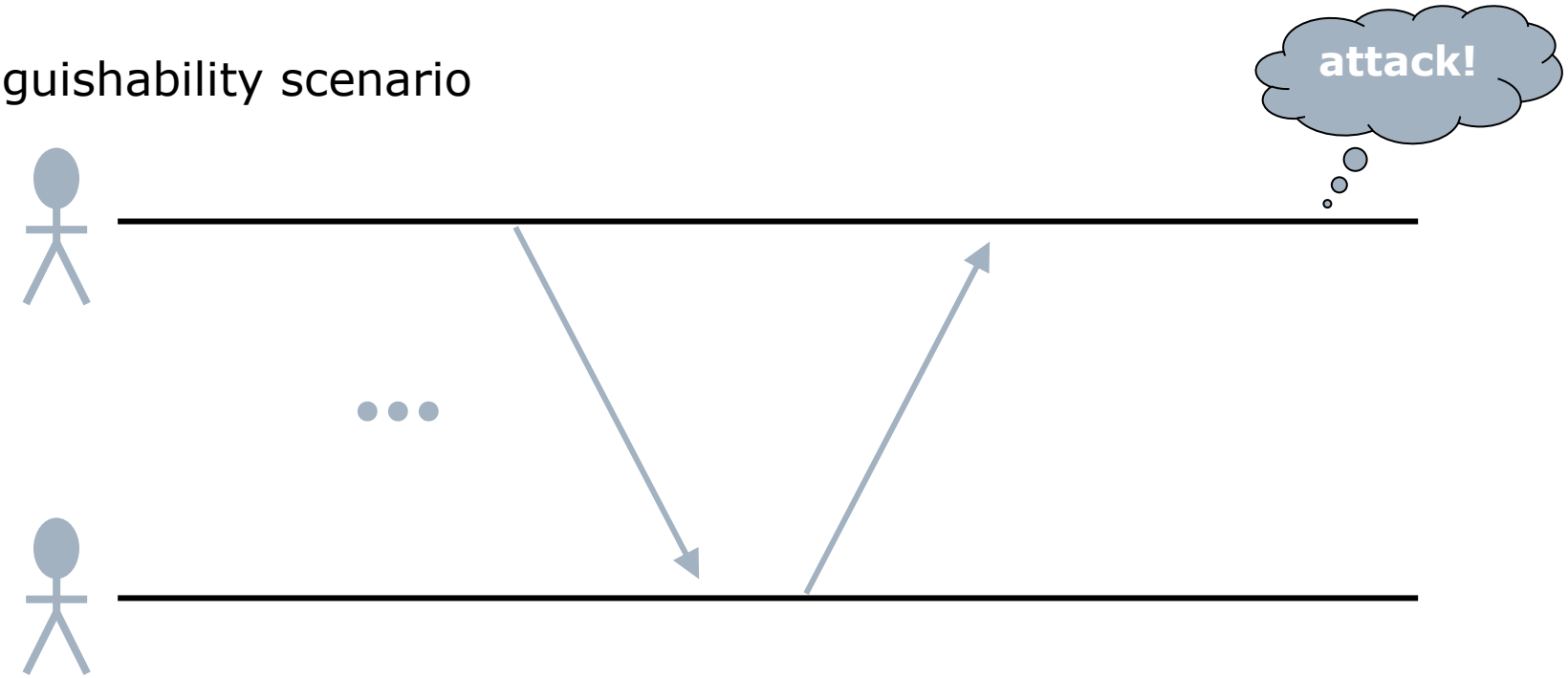


No Finite Protocol: Proof

- Then either this messenger is useless or one of the generals doesn't get a needed message.
- By the minimality of P, the last message is not useless so one of the generals doesn't march if the last message is lost.
- This contradiction proves that no such protocol P exists.

No Finite Protocol: Proof

Indistinguishability scenario



Last message needed

Unsolvable Problem

In any distributed protocol, the sender of the last message can’t tell whether it arrived.

That would require another message.

If communication reliability is any less than 100%, a consensus between two entities in a distributed network is impossible.

Unsolvable Problem

"No amount of user protocol can solve the problem in a manner to dissipate the anxiety of both parties as to the outcome of a transaction."

Two groups of gangsters need to coordinate by sending messages that may be lost.

Akkoyunlu E.A., Ekanadham K., and Huber R.V. (1975)
Some constraints and tradeoffs in the design of network communications.
Proc. 5th ACM Symposium on Operating Systems Principles (SOSP), ACM Press, pp. 67-74.

Two Insecure Lovers

• Alice and Bob want to schedule a meeting.

• If both attend, they win, but if only one attends, defeat and humiliation is felt.

• As a result, neither will show up without a guarantee that the other will show up at the same time.

Two Insecure Lovers

- Communication is by SMS only.
- Normally, it takes a message one hour to arrive.
- However, it is possible that it gets lost.

Two Insecure Lovers

• Fortunately, on this particular night, all the messages arrive safely.

• How long will it take Alice and Bob to coordinate their meeting?

Two Insecure Lovers

- Alice initiates the communication at noon.

- Bob receives a message at 1:00 from Alice saying “meet at midnight”. Should Bob show up?

Two Insecure Lovers

• Although her message was in fact delivered, Alice does not know. She therefore considers it possible that Bob did not receive the message.

• Hence Alice cannot decide to show up, given her current state of knowledge.

• Knowing this, Bob will not show up based solely on Alice's message.

Two Insecure Lovers

• Naturally, Bob reacts by sending an acknowledgment back to Alice, which arrives at 2:00.

• Will Alice plan to show up?

• Unfortunately, Alice's predicament is similar to Bob's predicament at 1:00, she cannot yet decide to show up.

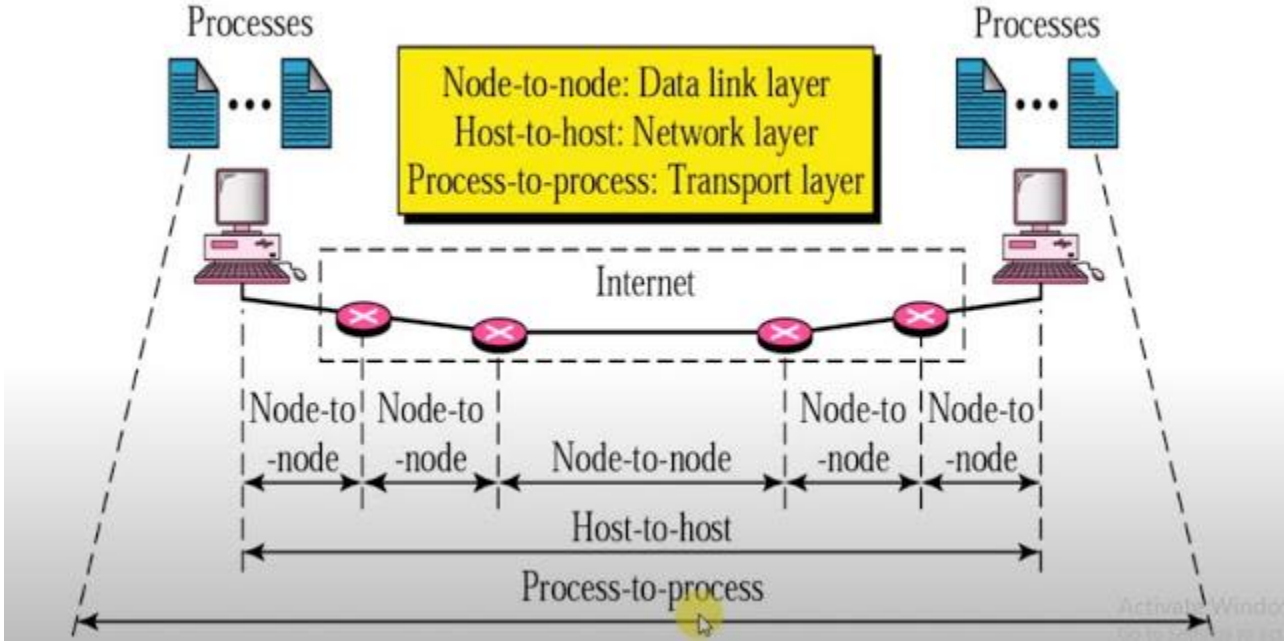
Two Insecure Lovers

• No number of successfully delivered acknowledgments will be enough to ensure that show up is safe!

• The key insight is that the difficulty is not caused by what actually happens (all messages actually arrive) but by the uncertainty regarding what might have happened.

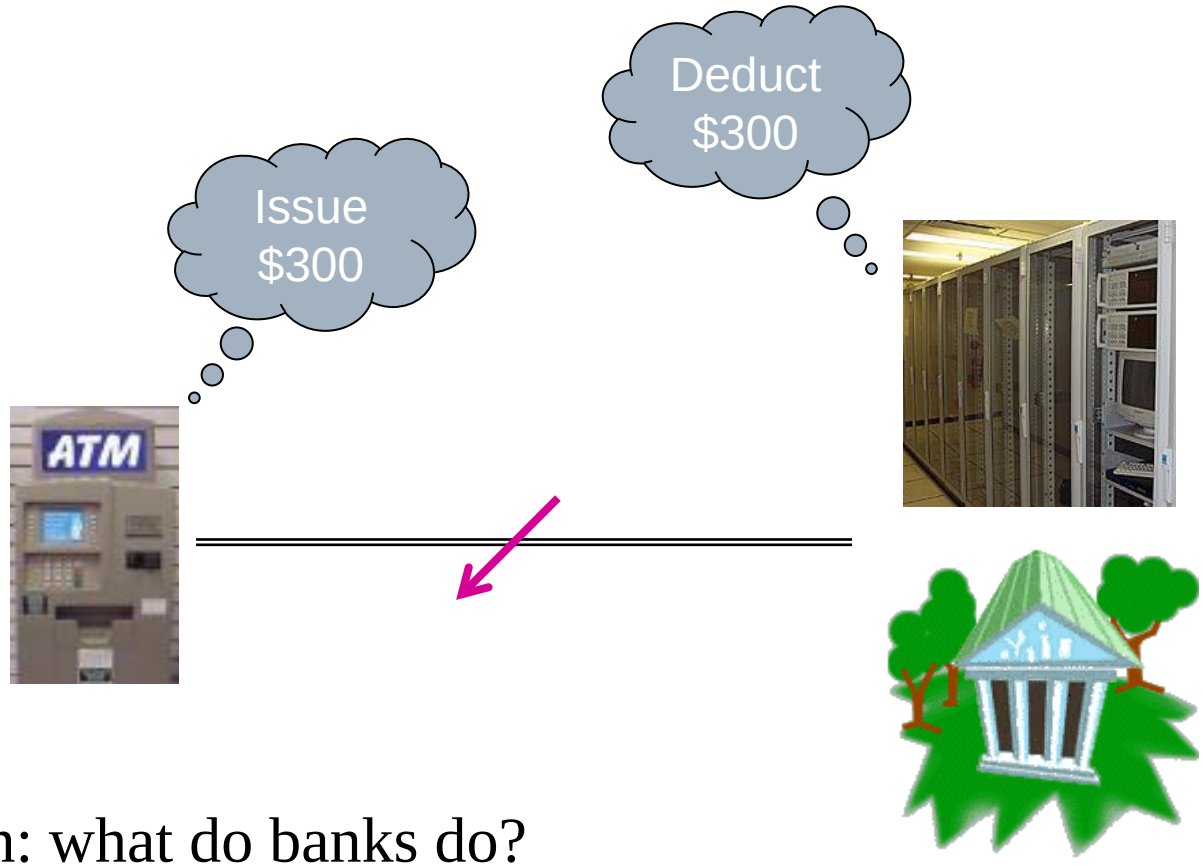
Two Generals Problem in TCP

Three-way handshakes



https://techietechtutorials.blogspot.com/2020/02/two-army-problem-in-computer-network.html

Two Generals in Practice



Question: what do banks do?