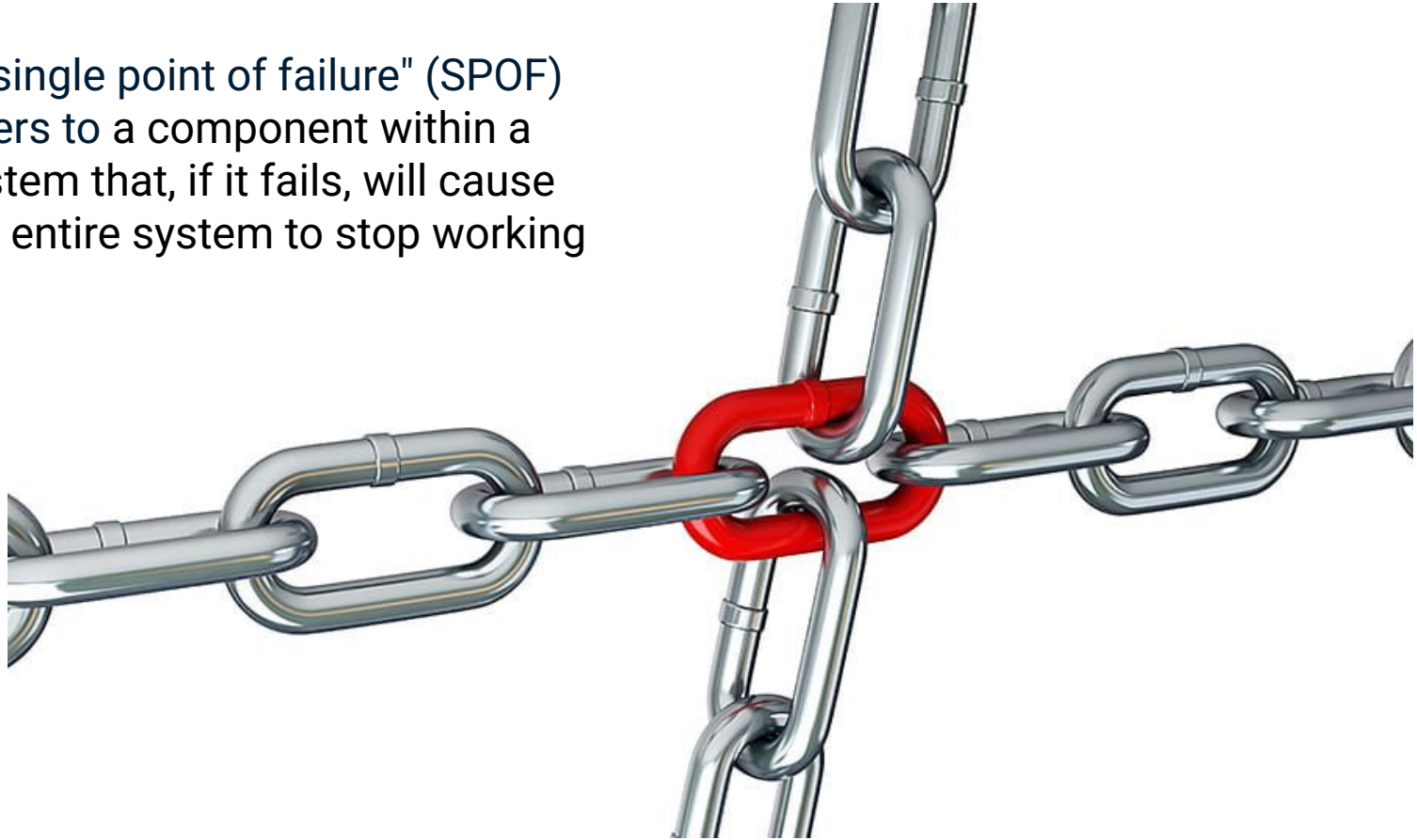
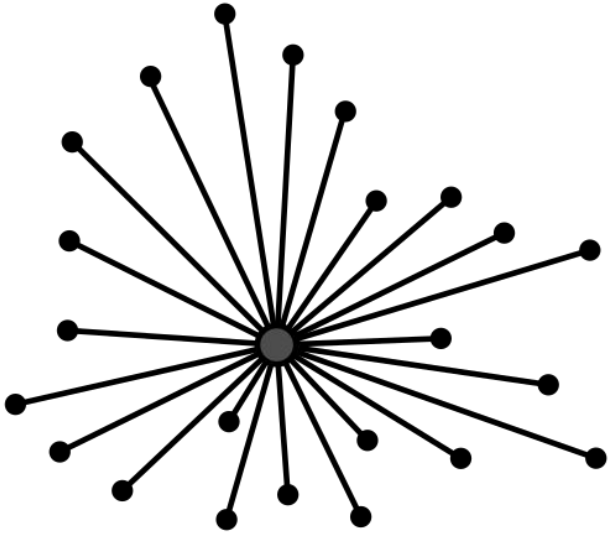
CSC 116 **Single Point of Failure & BFT**

A "single point of failure" (SPOF) refers to a component within a system that, if it fails, will cause the entire system to stop working





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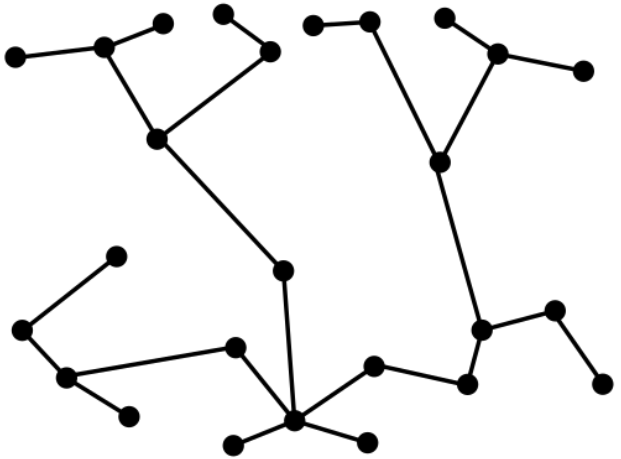

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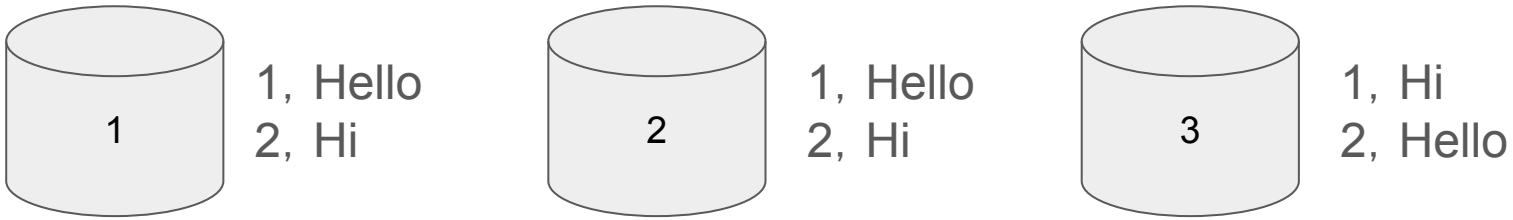
What we need to learn today:

How to make sure that all the datasets in different servers are the same datasets?



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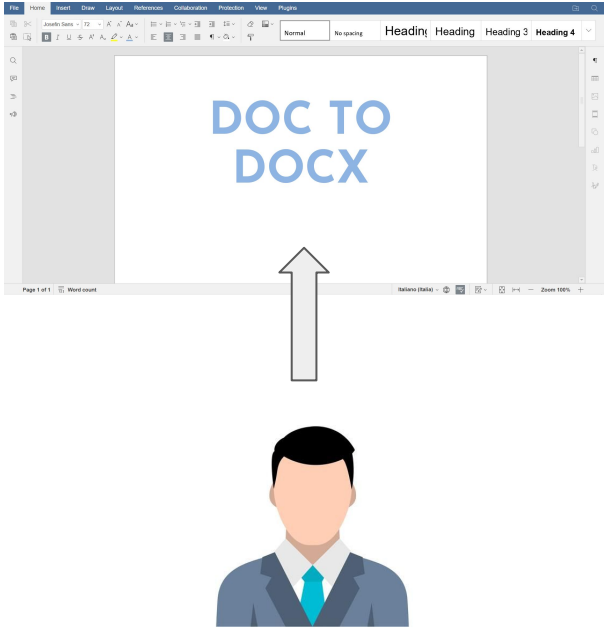
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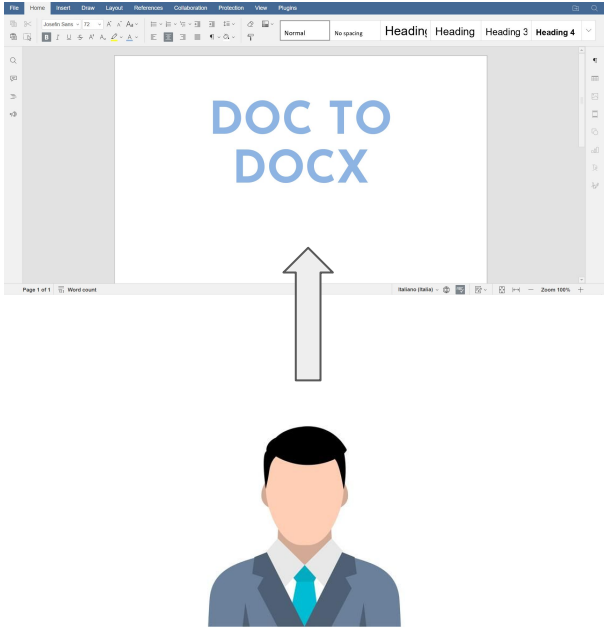
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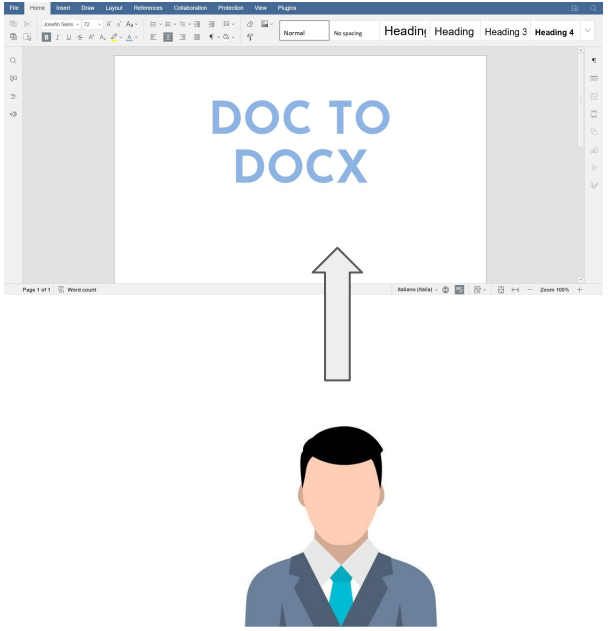
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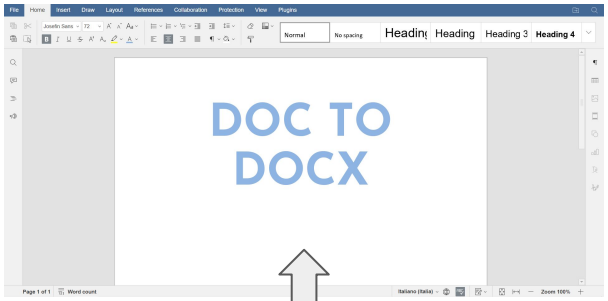
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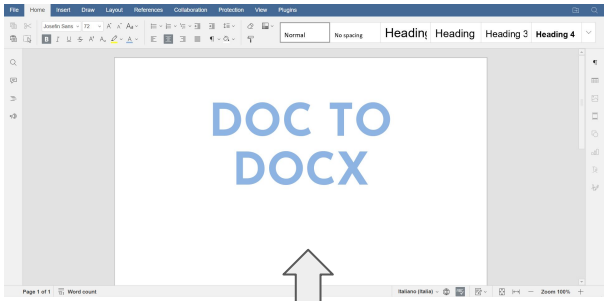
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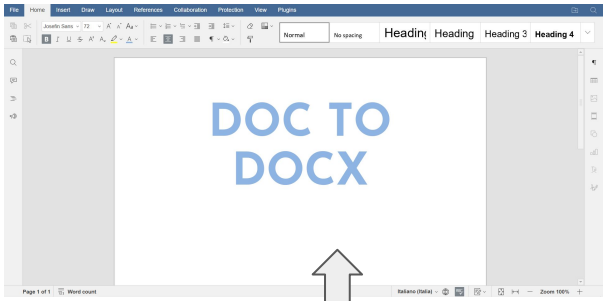
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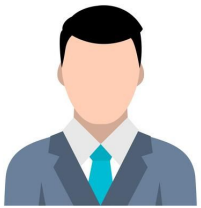
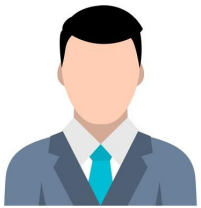




BFT

(Byzantine Fault Tolerance)

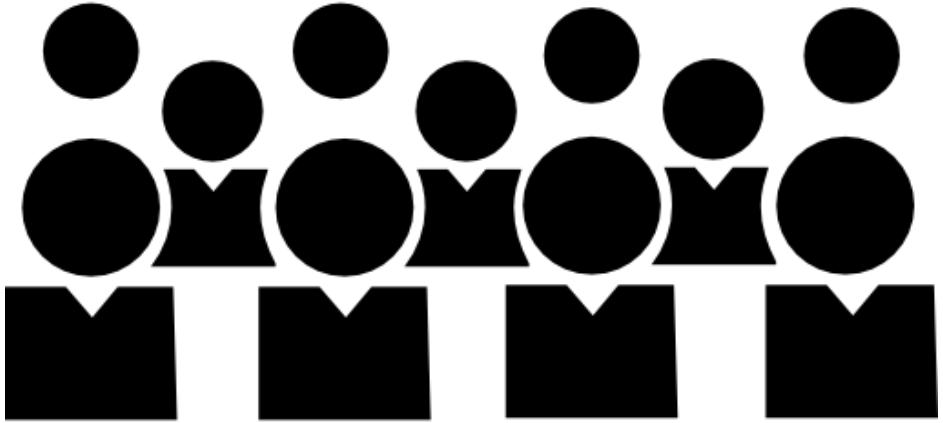
It’s an algorithm!

Fake news!

You don’t need to complete the assignment 2,
I will give you 8% for free.

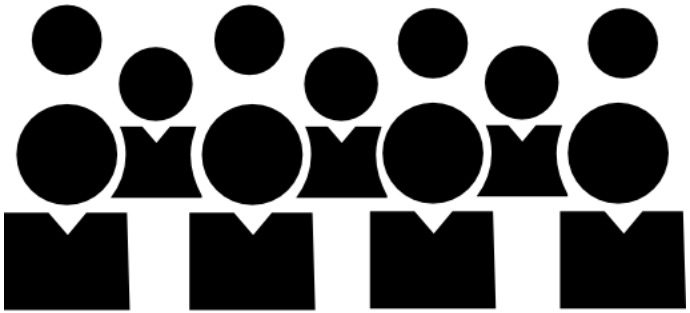
Yusen

Command



1. Yusen is
a global unique
hash code!

2. You are all real AI models. Your brains tell you: 1). Yusen is a real person and he is the instructor of this course. 2) He is in the class, we are face to face, 3). I clearly hear what he said in the classroom.



All of you in this classroom will trust that this is a real command. But the students not here may not trust. It should be a joke!!

Let’s make some conclusions:
What you find in this game?

Consensus

1 Your eyes record all the students, they are all evidences

2 You heard the leader's command, and the leader is trusted (I am a real instructor)

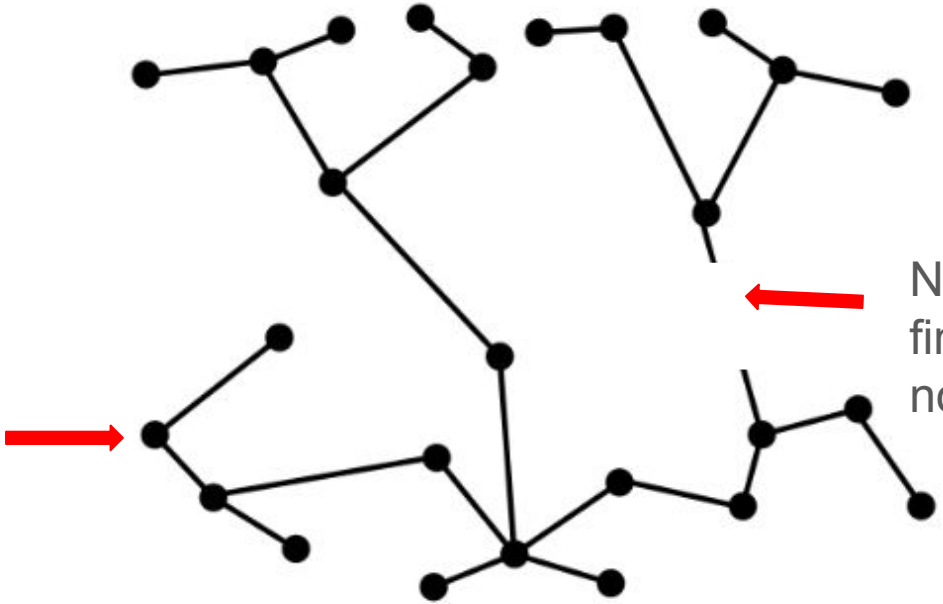
3 Your brain tells you it is true

Other Students May not Trust you

1 You are not a leader, it sounds not real

2 You may be joking

3 They are not in the classroom, they did not hear it and experience it.



Network broken! But it is fine. Because majority nodes are honest nodes

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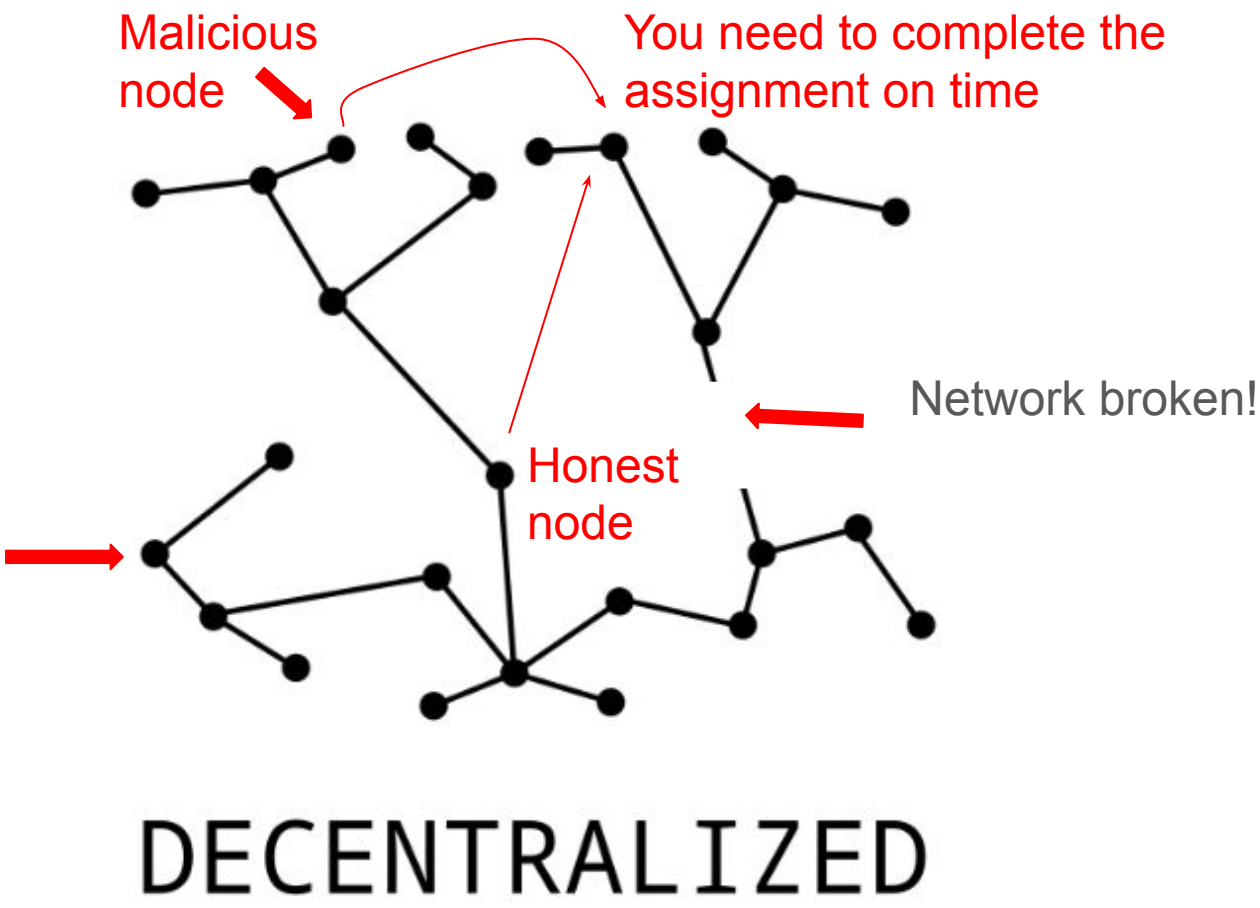
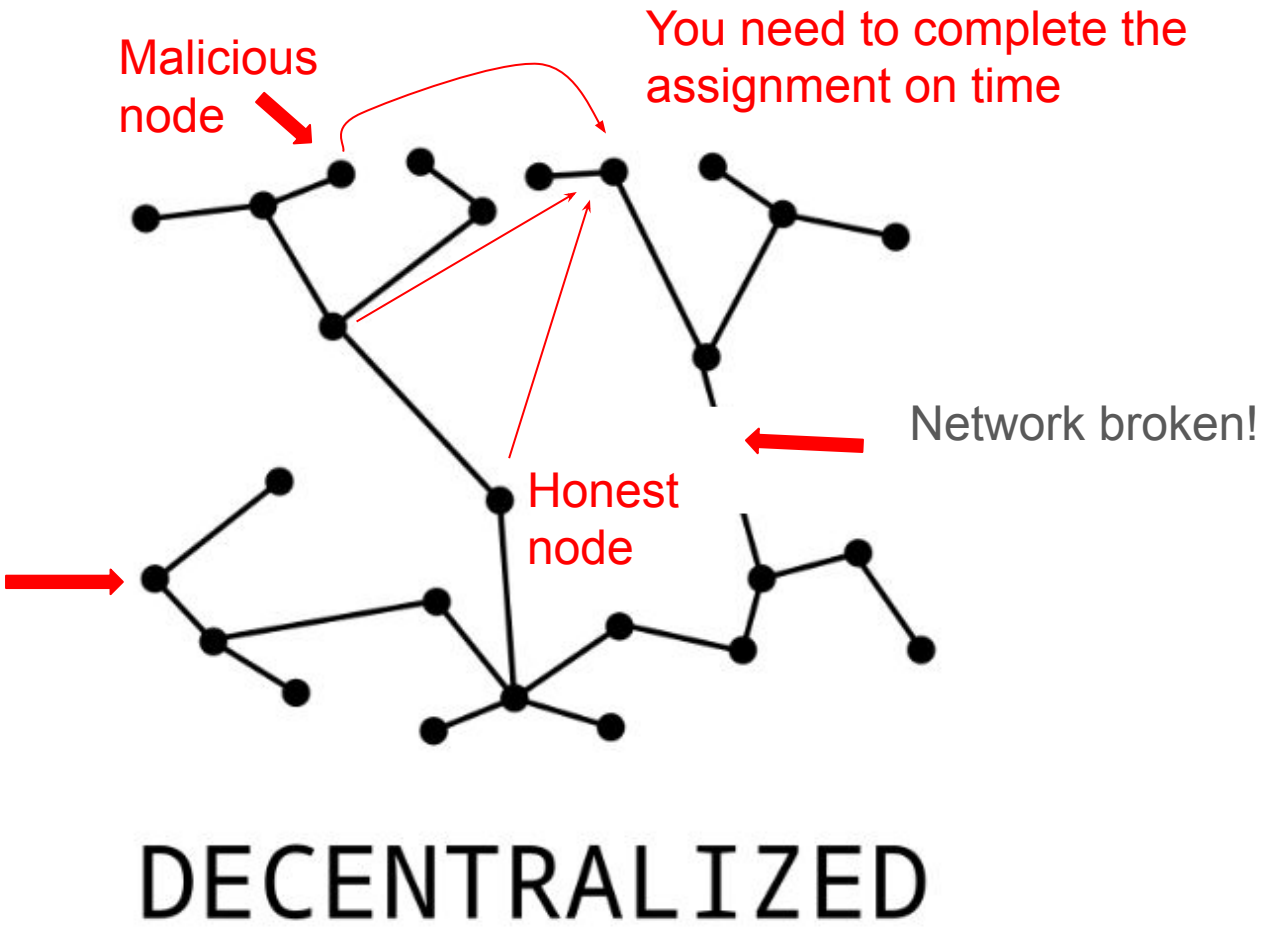

Malicious node
You need to complete the assignment on time
Network broken!
Honest node
DECENTRALIZED

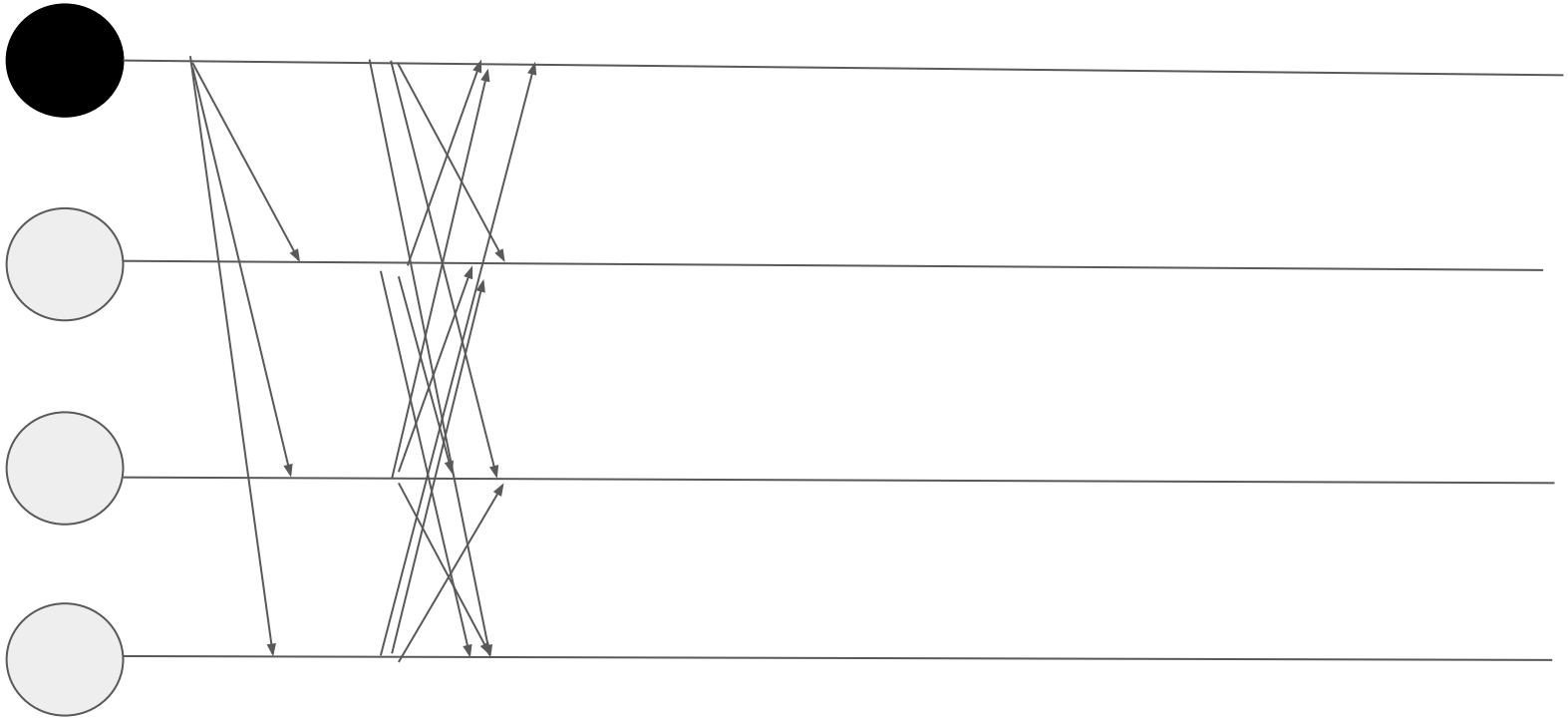

Malicious node
You need to complete the assignment on time
Network broken!
Honest node
DECENTRALIZED

Phase 0: Leader broadcast messages to all the students (nodes)

Phase 0

Phase 1: All the nodes start to broadcast messages

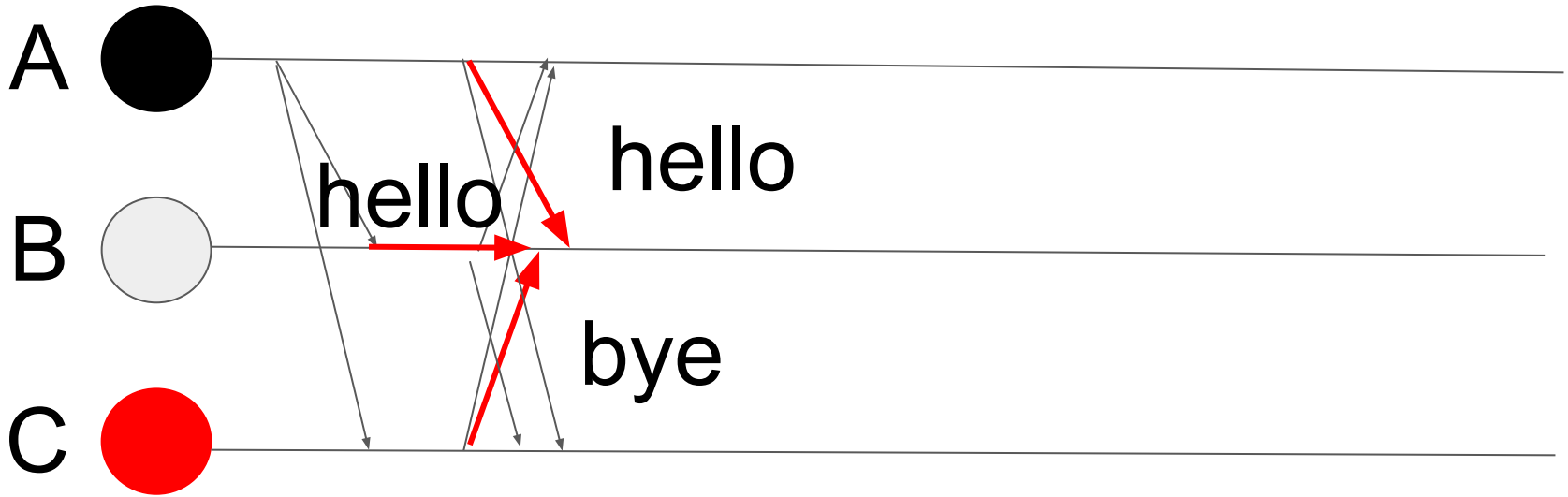
Phase 0 Phase 1



Why need to broadcast messages？

Phase 0 Phase 1

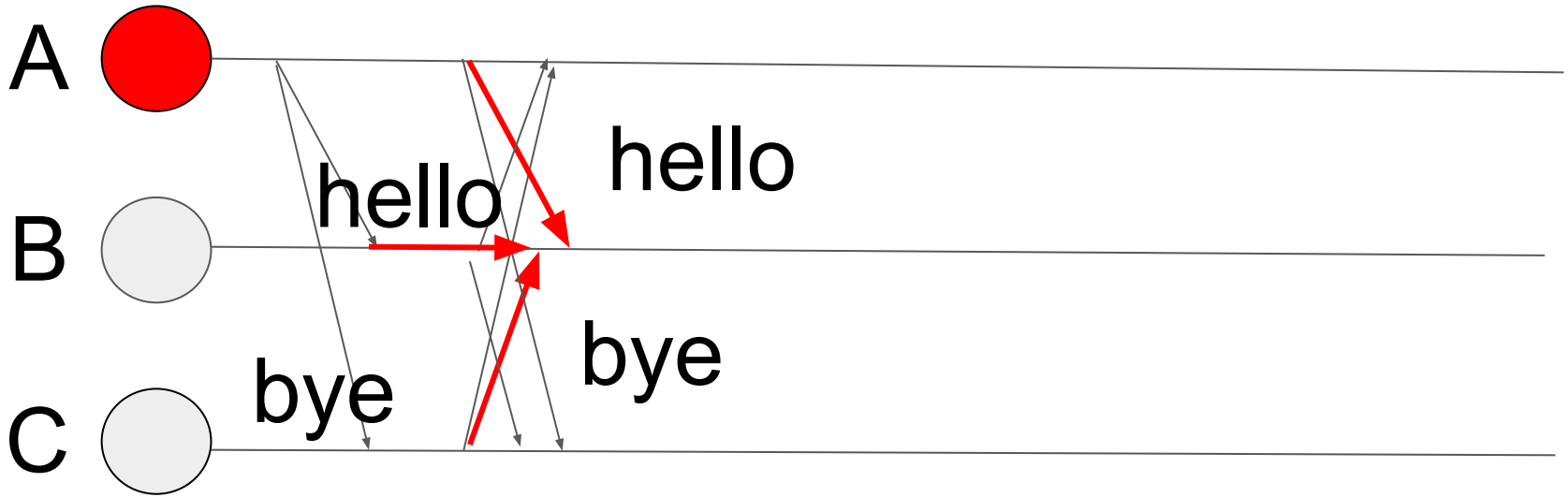
Malicious students



B: (hello), hello, bye

Phase 0 Phase 1

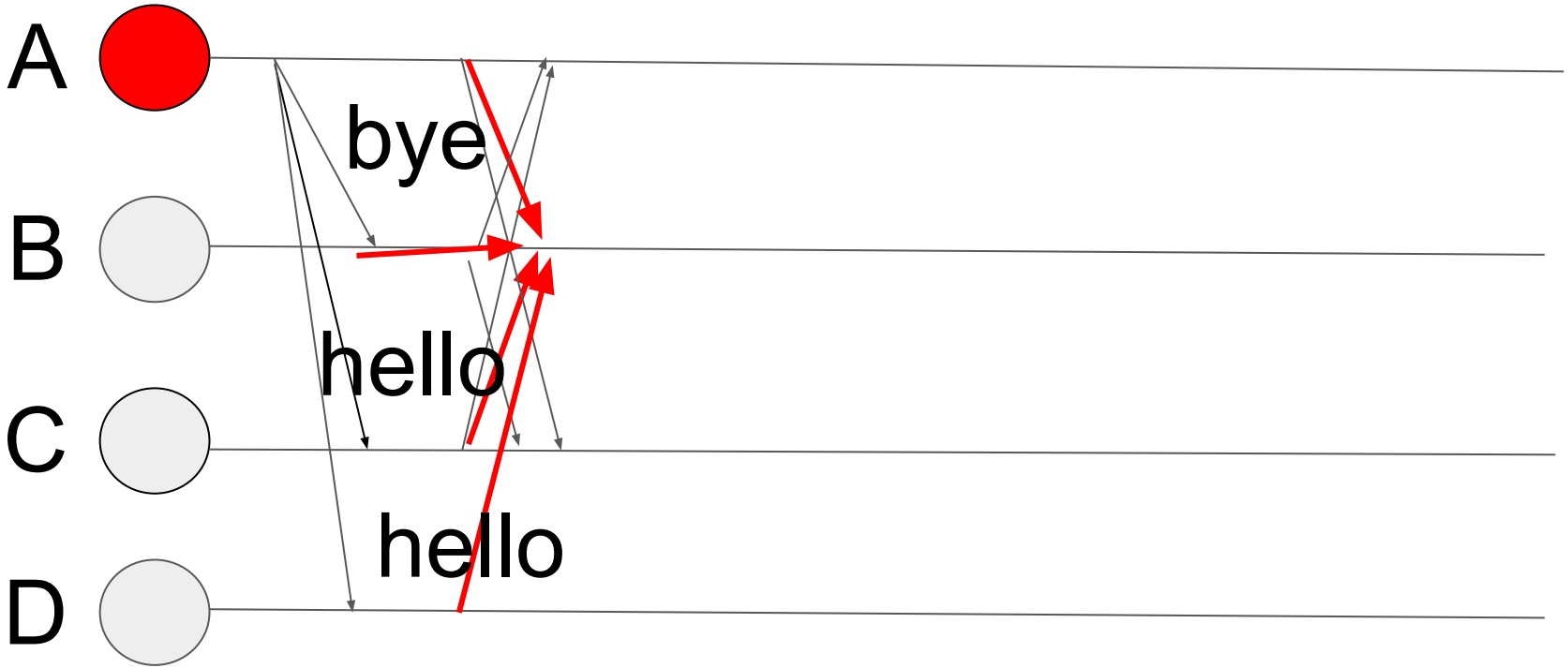
Malicious leader



B: (hello), hello, bye

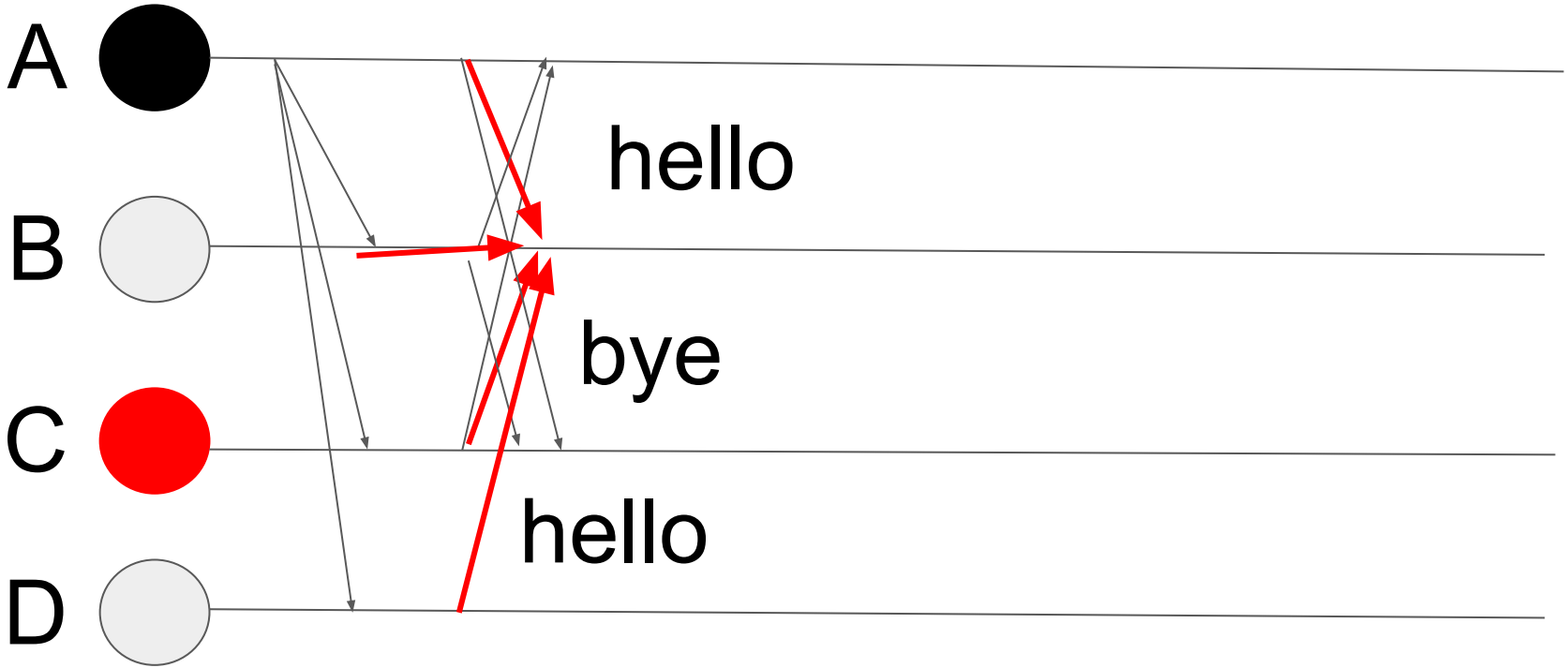
C: (bye), bye, hello

Phase 0 Phase 1



B: (bye), bye, hello, hello

Phase 0 Phase 1



B: (hello), hello, hello, bye

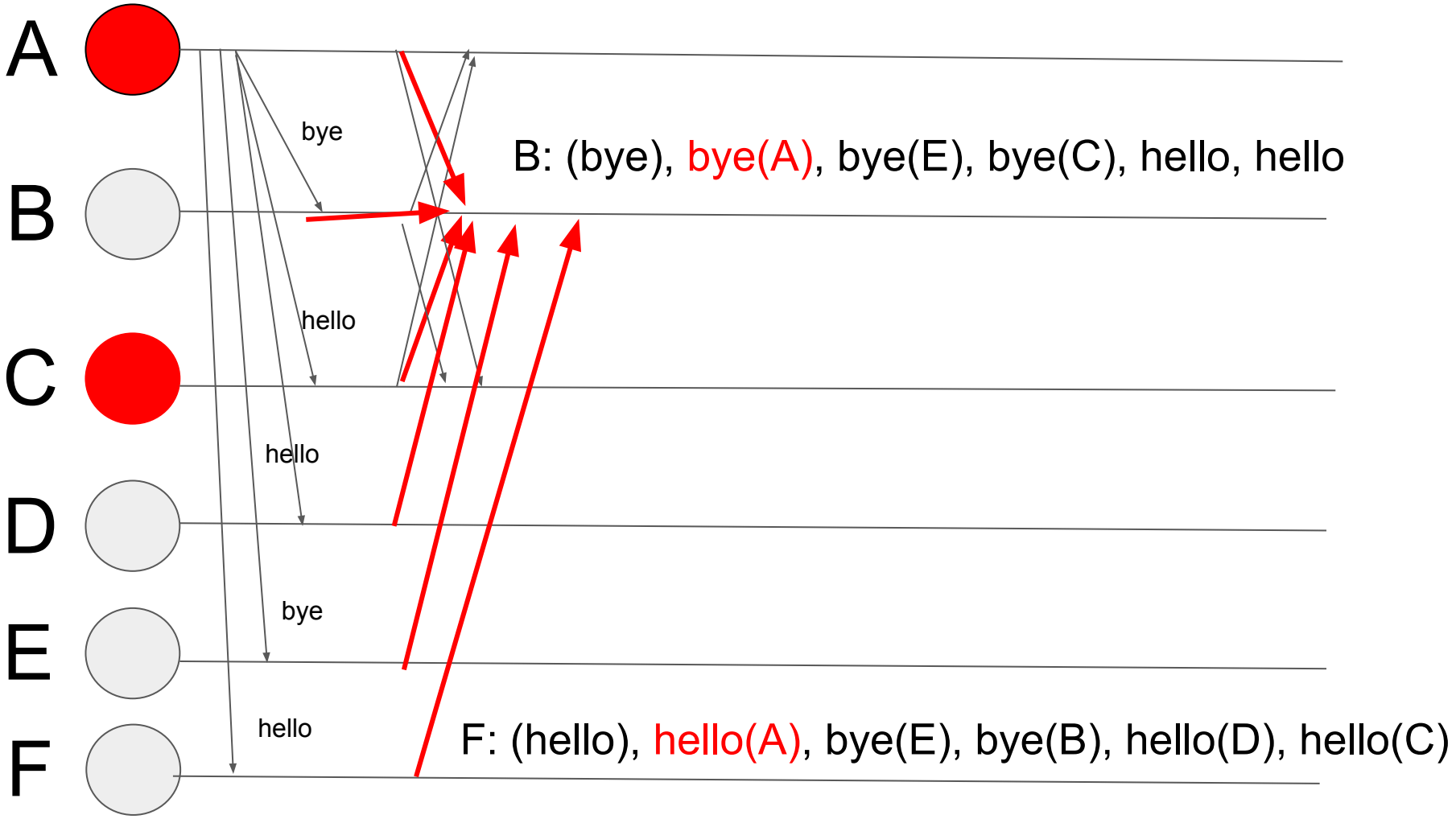
n: total nodes

f: total number of malicious nodes

n - f > f : the number of correct students needs to large than the number of malicious students.

$$n > 2f$$

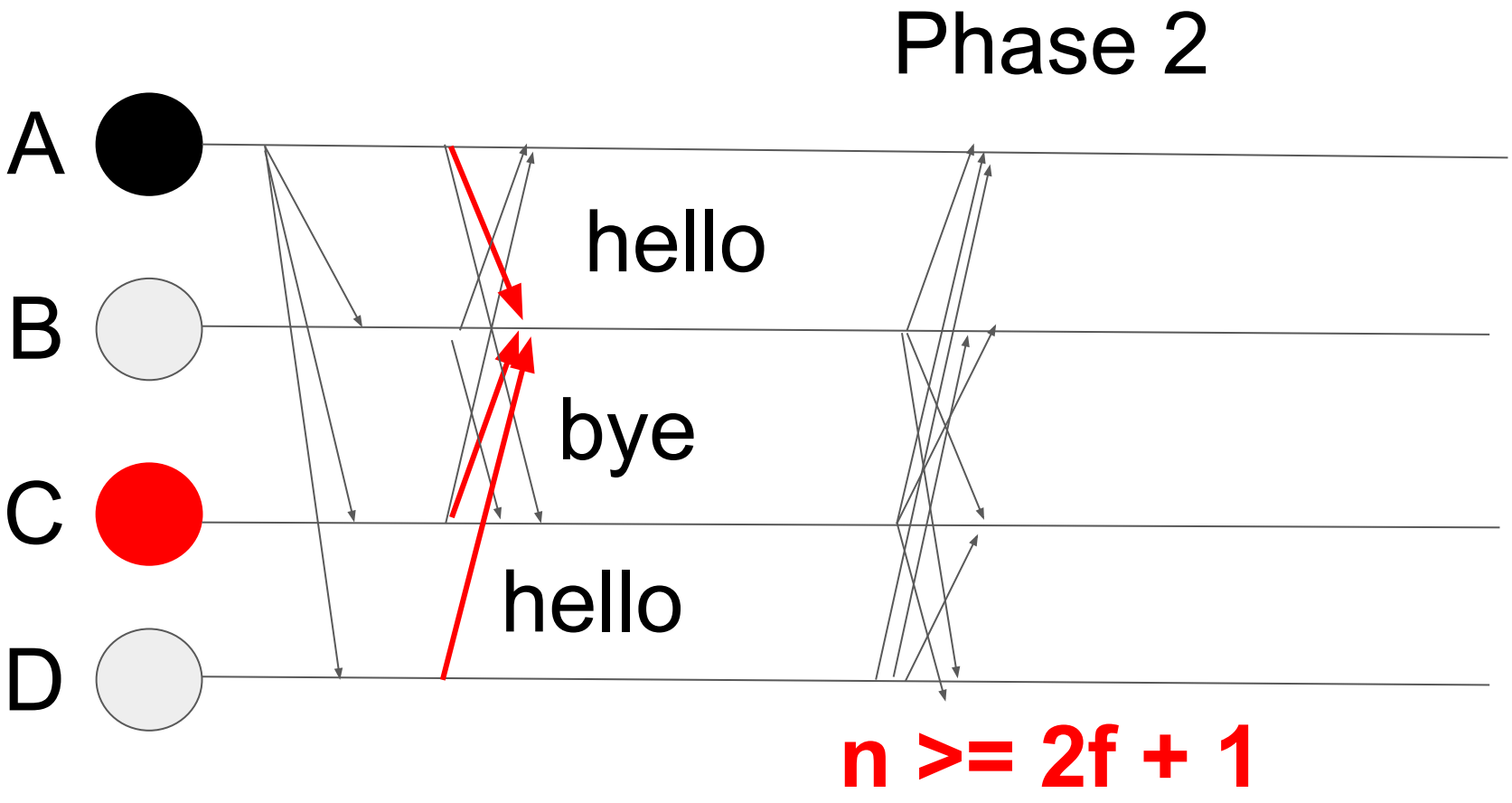
$$n >= 2f + 1$$


A
B
C
D
E
F
bye
hello
hello
bye
hello
B: (bye), bye(A), bye(E), bye(C), hello, hello
F: (hello), hello(A), bye(E), bye(B), hello(D), hello(C)

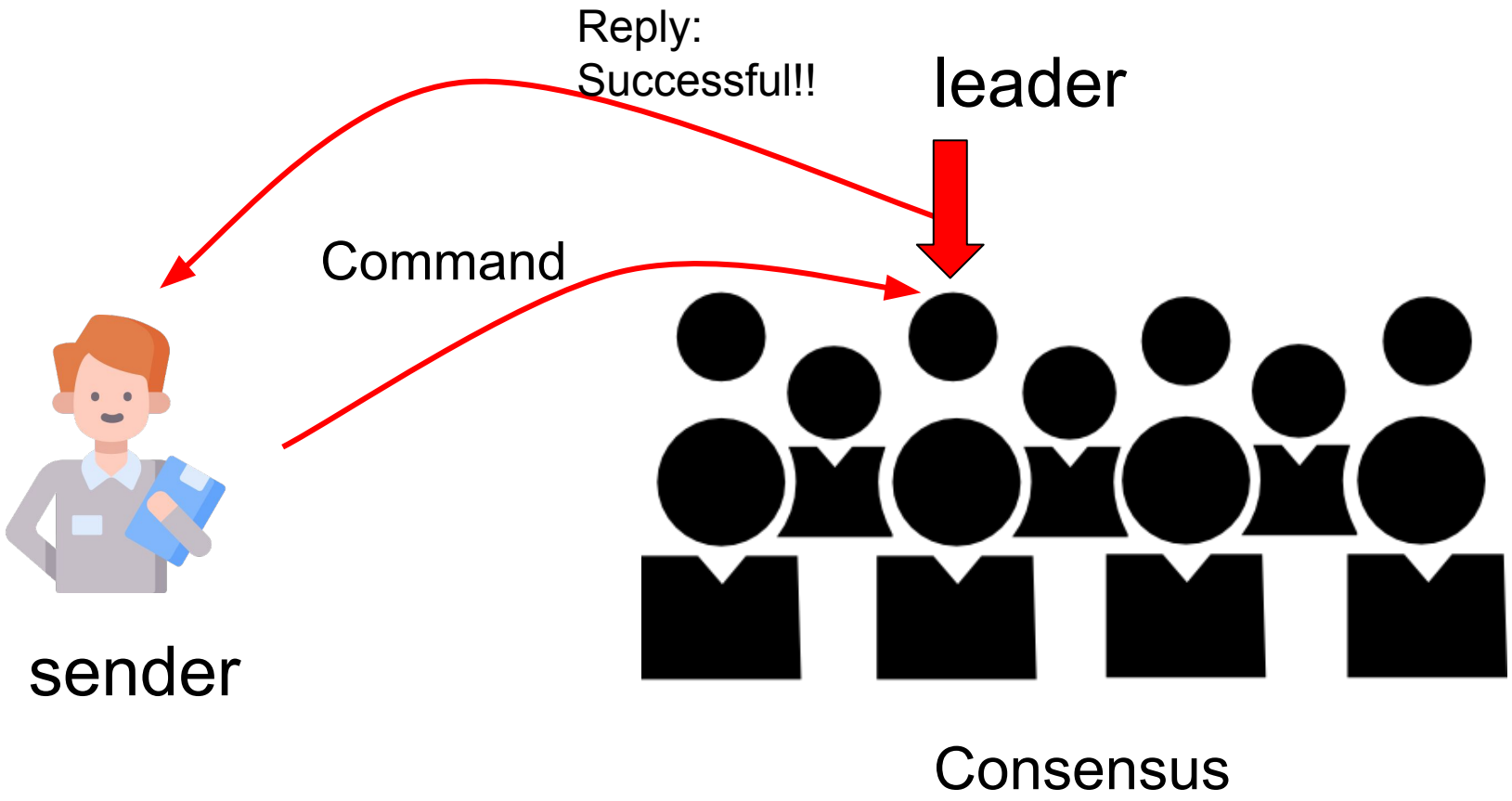
4 nodes can tolerate 1
5 nodes can tolerate 1
6 nodes can tolerate 1
7 nodes can tolerate 2
8 nodes can tolerate 2
9 nodes can tolerate 2
10 nodes can tolerate 3

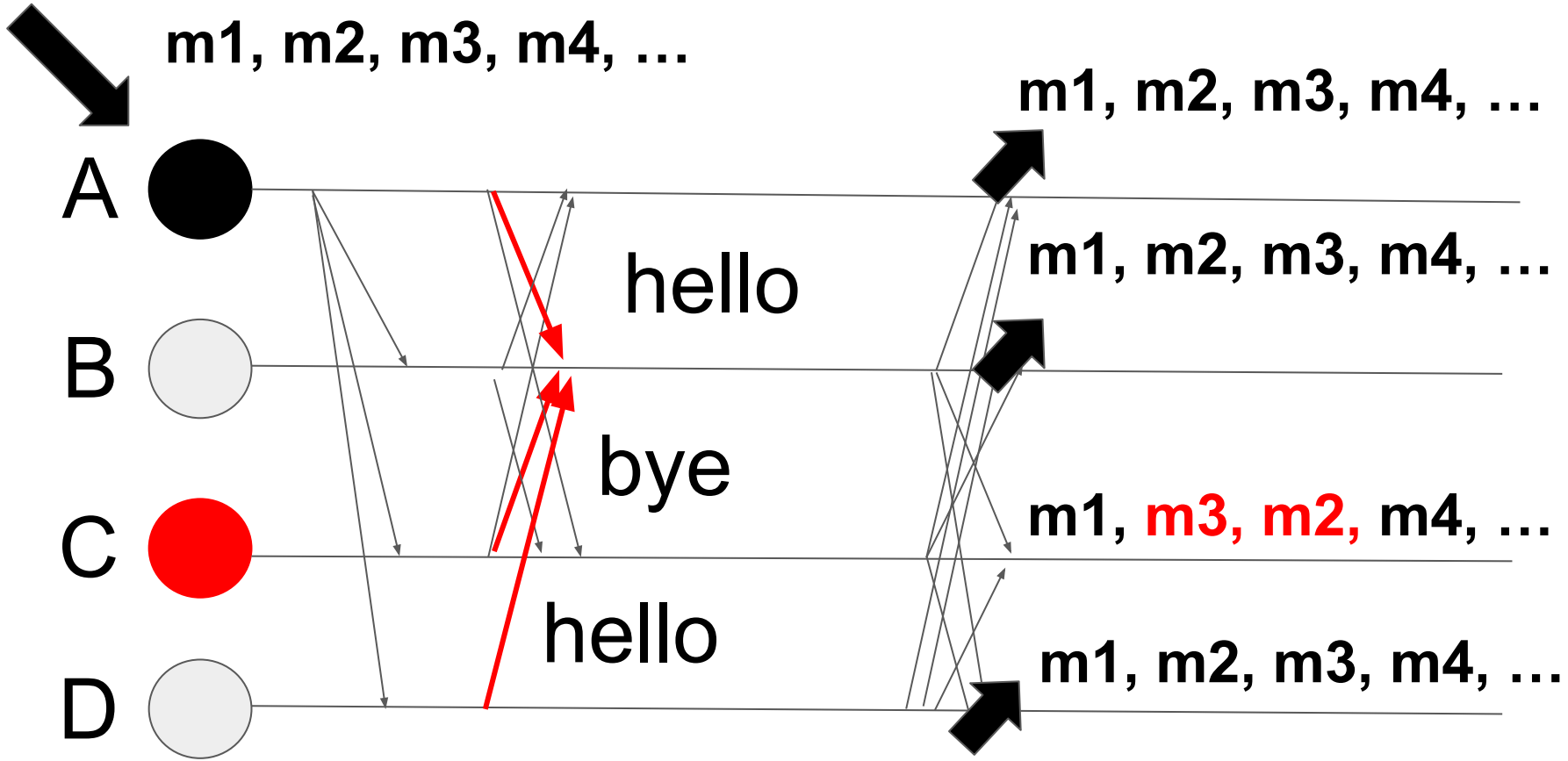
$$n >= 3f + 1$$

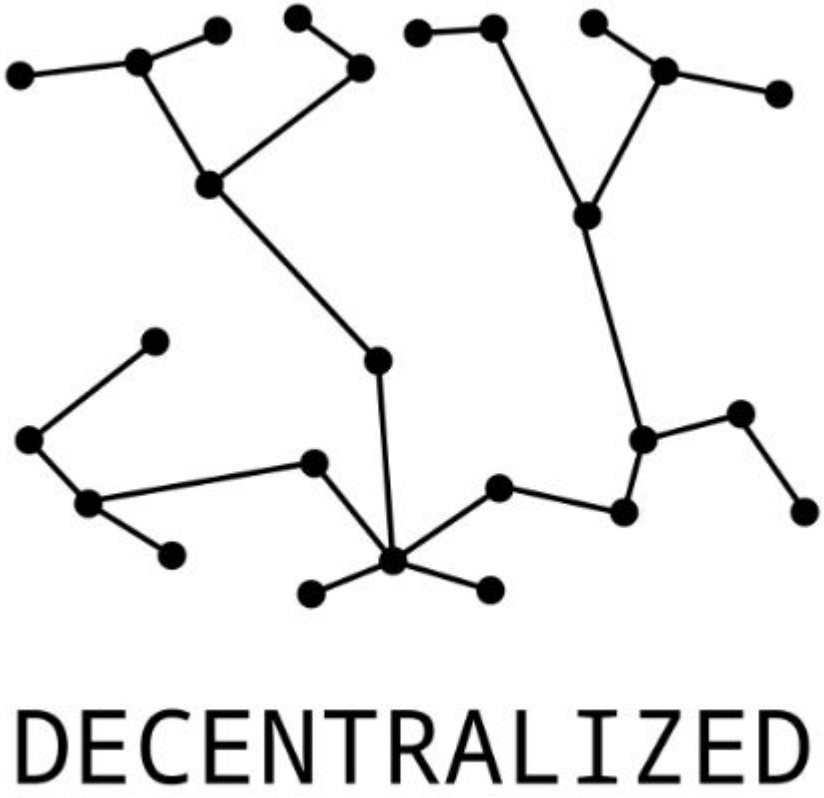
Phase 2: Confirm the Message to everyone and leader


Phase 2
A
B
C
D
hello
bye
hello
n >= 2f + 1

Totality: Total order

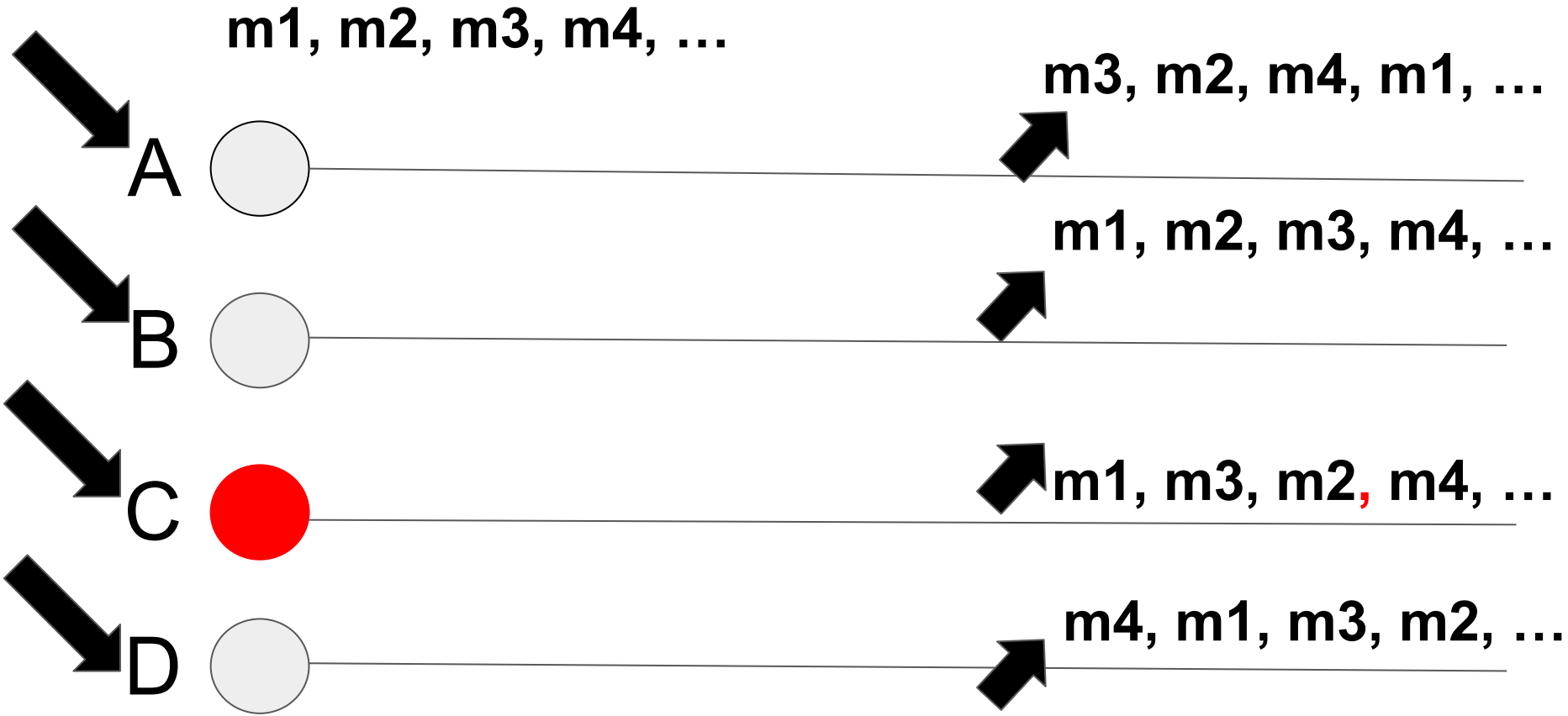

Reply:
Successful!!
leader
Command
sender
Consensus


m1, m2, m3, m4, …
A
B
C
D
hello
bye
hello
m1, m2, m3, m4, …
m1, m2, m3, m4, …
m1, m3, m2, m4, …
m1, m2, m3, m4, …



Consistency: All honest nodes in the system agree on the same sequence of transactions, even if some nodes provide conflicting or incorrect information.

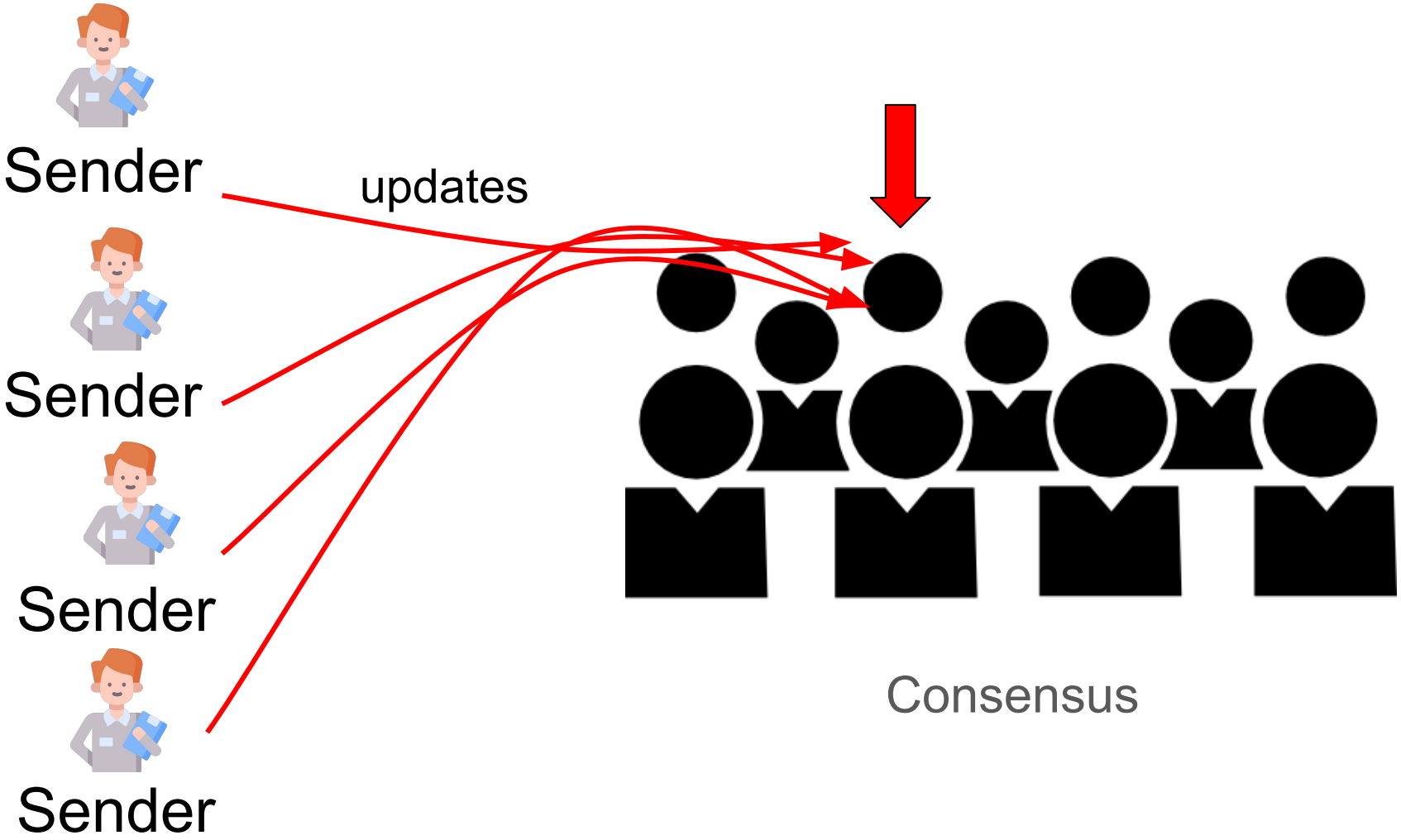
Fault Tolerance: BFT systems can tolerate up to (n-1)/3 faulty nodes in a network of n nodes, ensuring system availability and correctness despite failures.

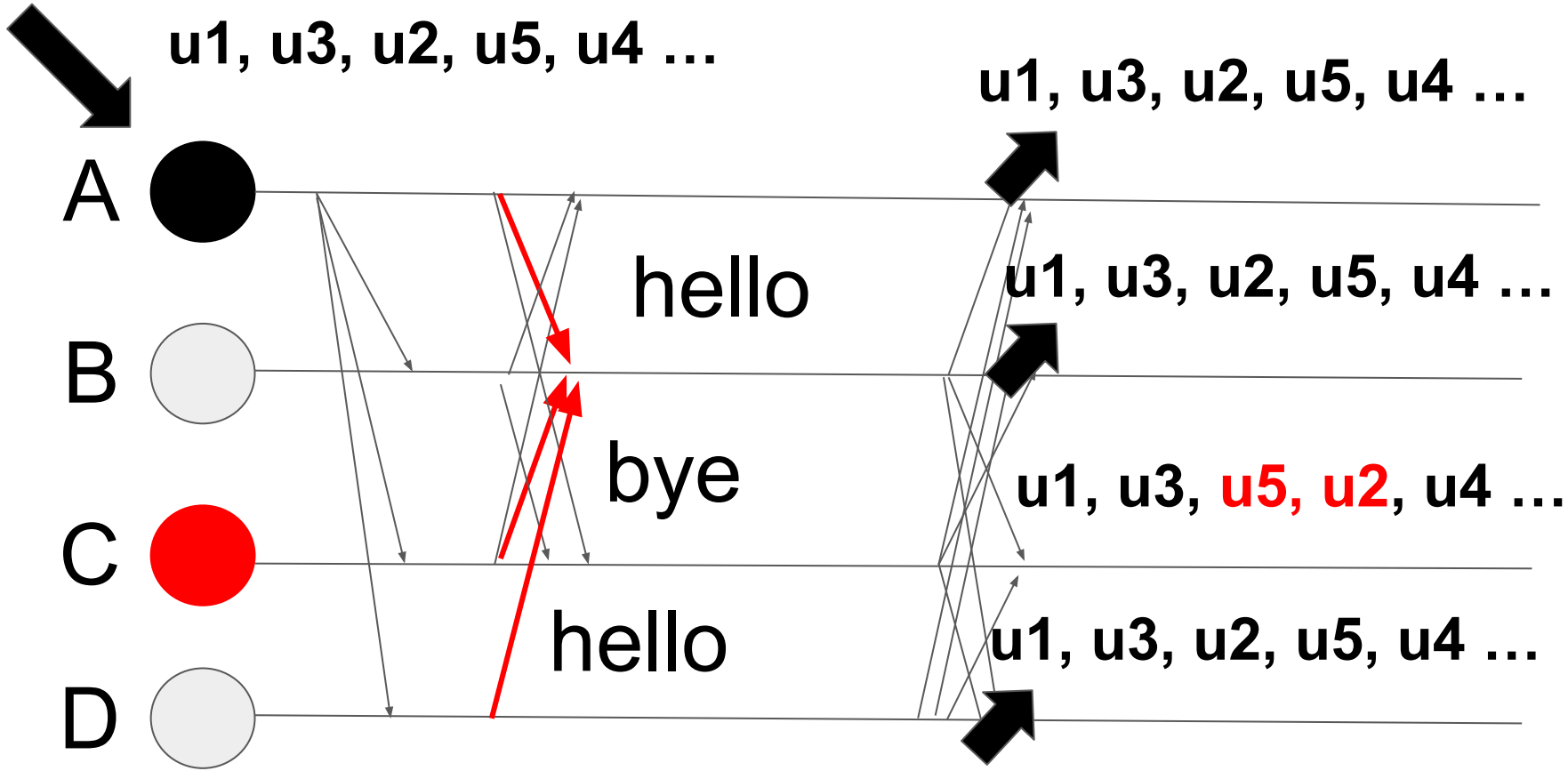

m1, m2, m3, m4, …
A
B
C
D
m3, m2, m4, m1, …
m1, m2, m3, m4, …
m1, m3, m2, m4, …
m4, m1, m3, m2, …

Sequence 1: Update Email = “12345@gmail”

Sequence 2: Update Email = “6789@gmail”

The database will update seq 2 first and then seq 1


Sender
Sender
Sender
Sender
updates
Consensus


u1, u3, u2, u5, u4 …
A
B
C
D
hello
bye
hello
u1, u3, u2, u5, u4 …
u1, u3, u2, u5, u4 …
u1, u3, u5, u2, u4 …
u1, u3, u2, u5, u4 …

A simple example to conclude the workflow:

Step1: I send message to the leader.

Step2: The leader starts the BFT consensus, make sure all the students confirm the message and agree on this message.

Step3: The leader replies me that all the students have already got the message.

Step4: Done! I will start to send a new message to the leader to start a new consensus.

Why we need BFT?

1, Improve data consistency.
2, Improve system availability.
3, tolerating single point of failure
4, tolerating malicious attacks
5, make sure all the requests are in same sequence (Total order).

Financial Transaction Systems

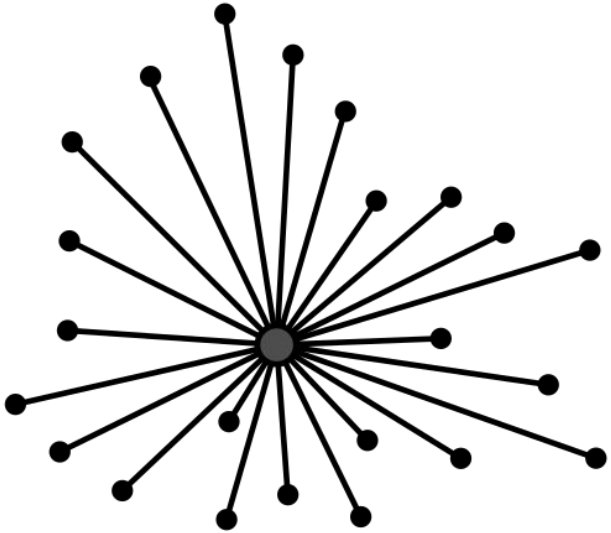
- **Why BFT matters**: Ensures the correct sequence of financial transactions, preventing fraud or errors caused by malicious actors.

Distributed Databases

- **Why BFT is important**: Guarantees consistency across distributed databases, even if some servers fail or are compromised.

Blockchain and Cryptocurrencies

- **Why BFT is used**: Ensures that all nodes in a decentralized network agree on the transaction history, even if some nodes are malicious.



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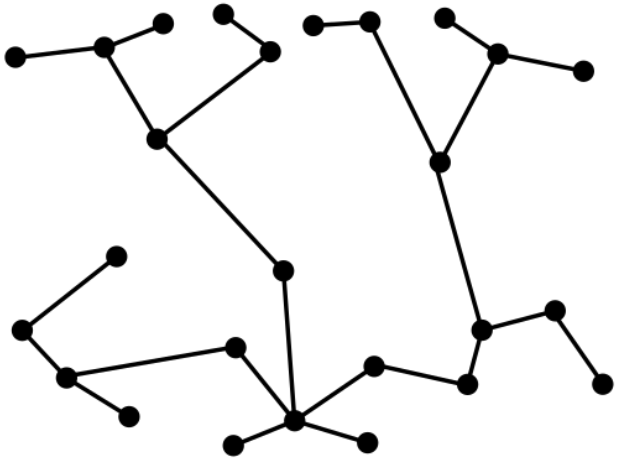

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Drawbacks of BFT

Time-Consuming Consensus Process

Scalability Issues

Leader Bottleneck

High Latency

Maintenance and Complexity

Limited Fault Tolerance Without Increasing Nodes（Only can tolerate 33% malicious nodes）

Vulnerable to Network Delays