Peer-to-Peer Architecture

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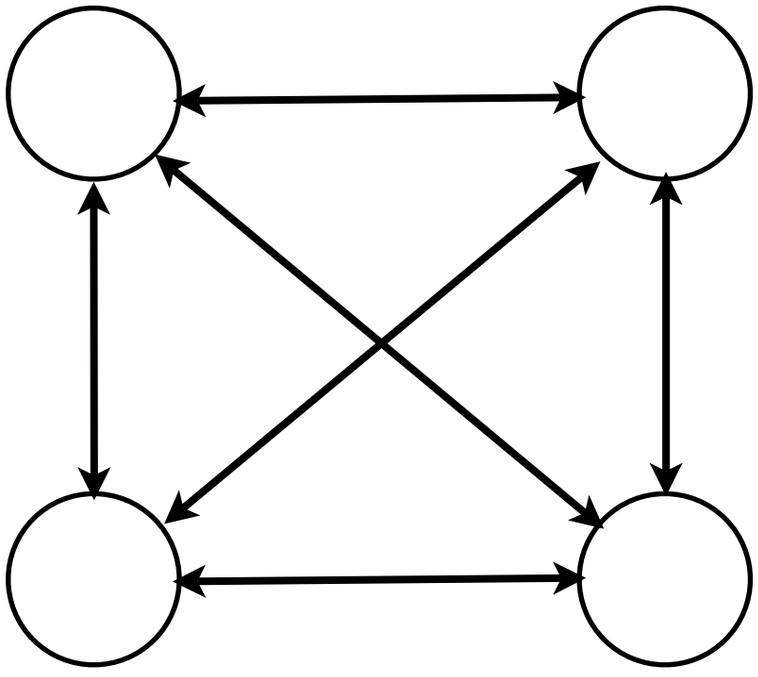


Role of clients

Notify clients

Resolve conflicts

Maintain states

Simulate games

Latency

Robustness

Conflict/Cheating

Consistency

Accounting

Scalability

Complexity

Lower Latency

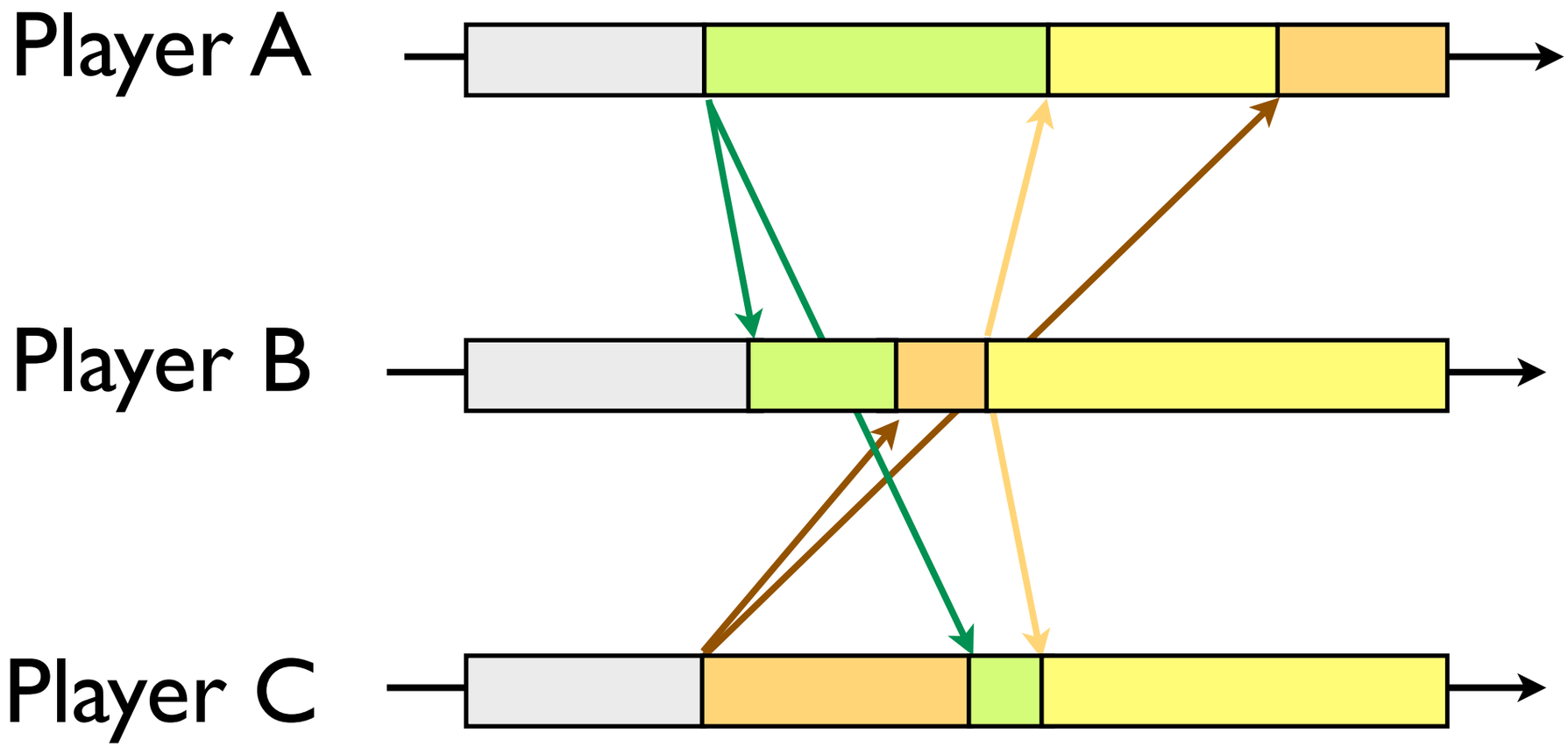
No Single Point of Failure

MiMaze from INRIA, France

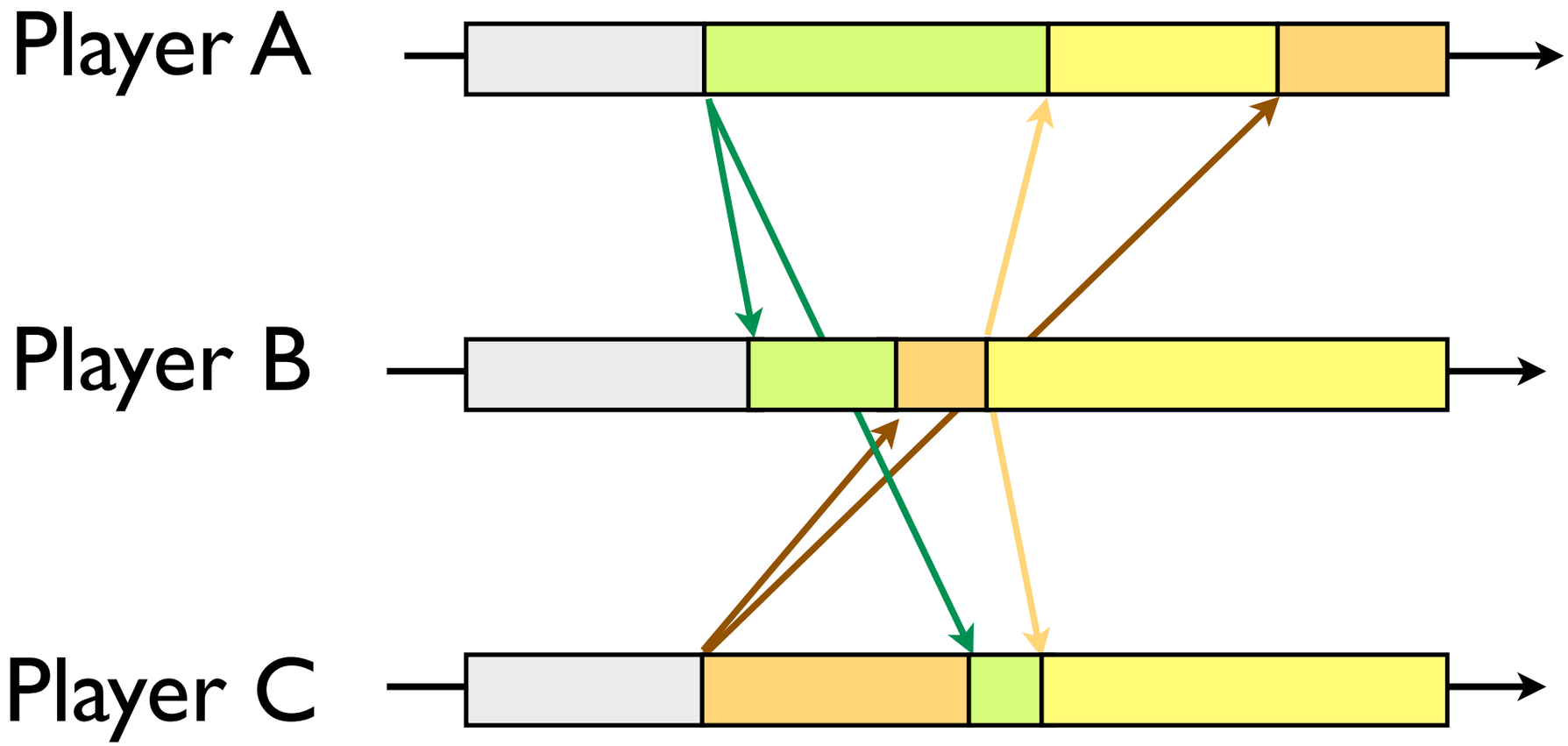
Age of Empire Series

http://compactiongames.about.com/library/games/screenshots/blscreens-ageofkings.htm

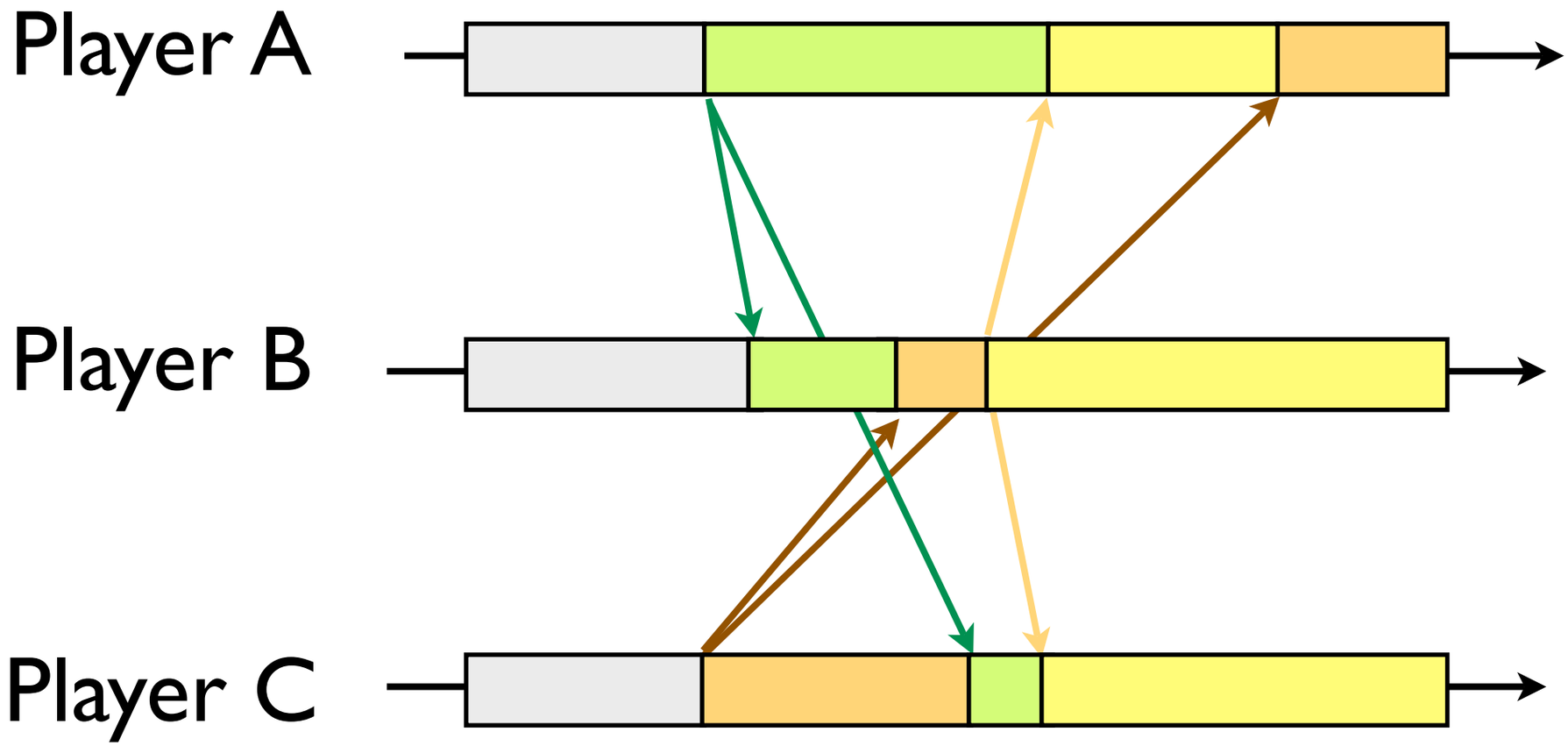
Without a server with authority, we can easily get into inconsistent states.



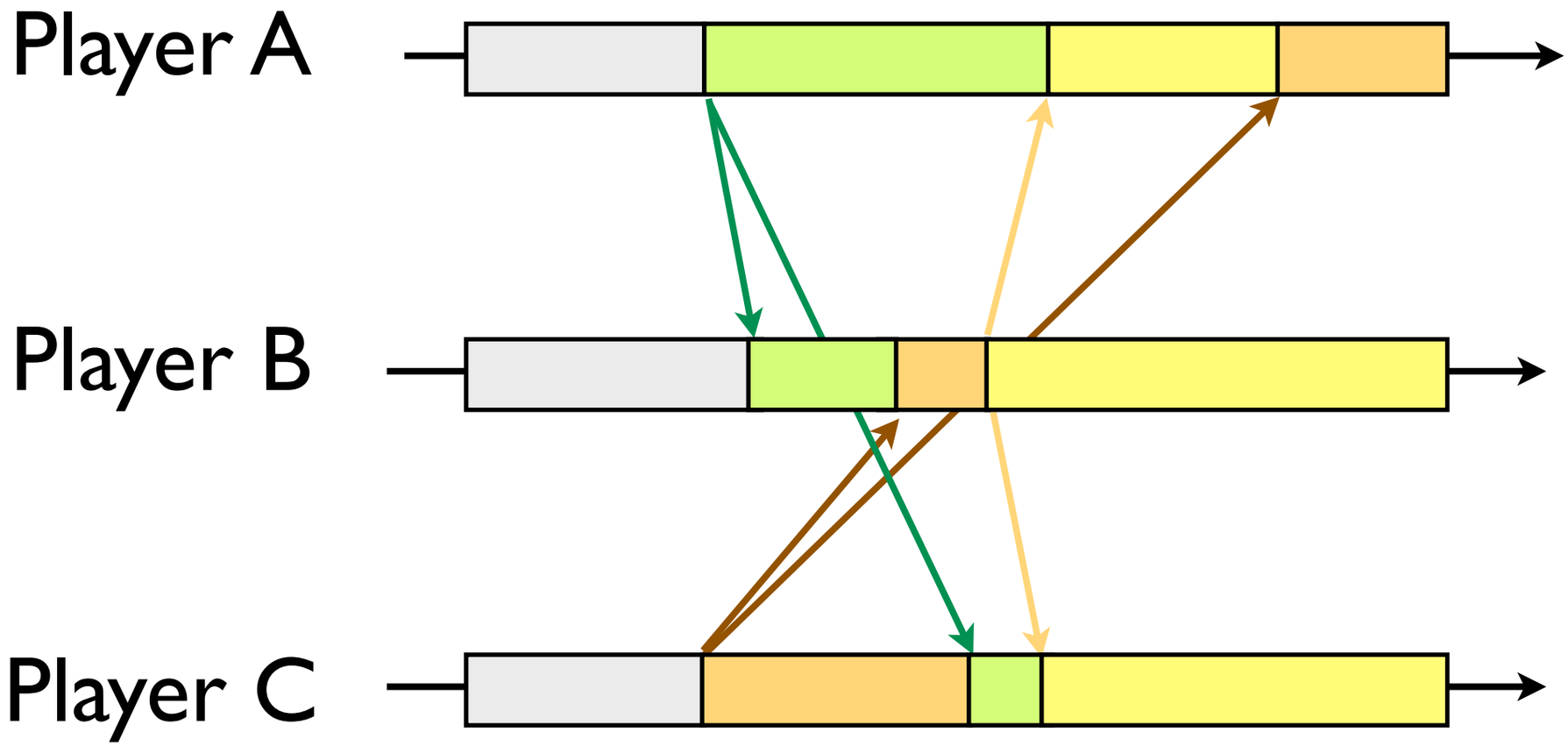
Problem: order of messages received are wrong.



Idea: If we synchronize the clocks of all players and timestamp each message, we can know the right order of execution.



Problem: When to execute? (Is there another message generated earlier than this that is still on its way here?)



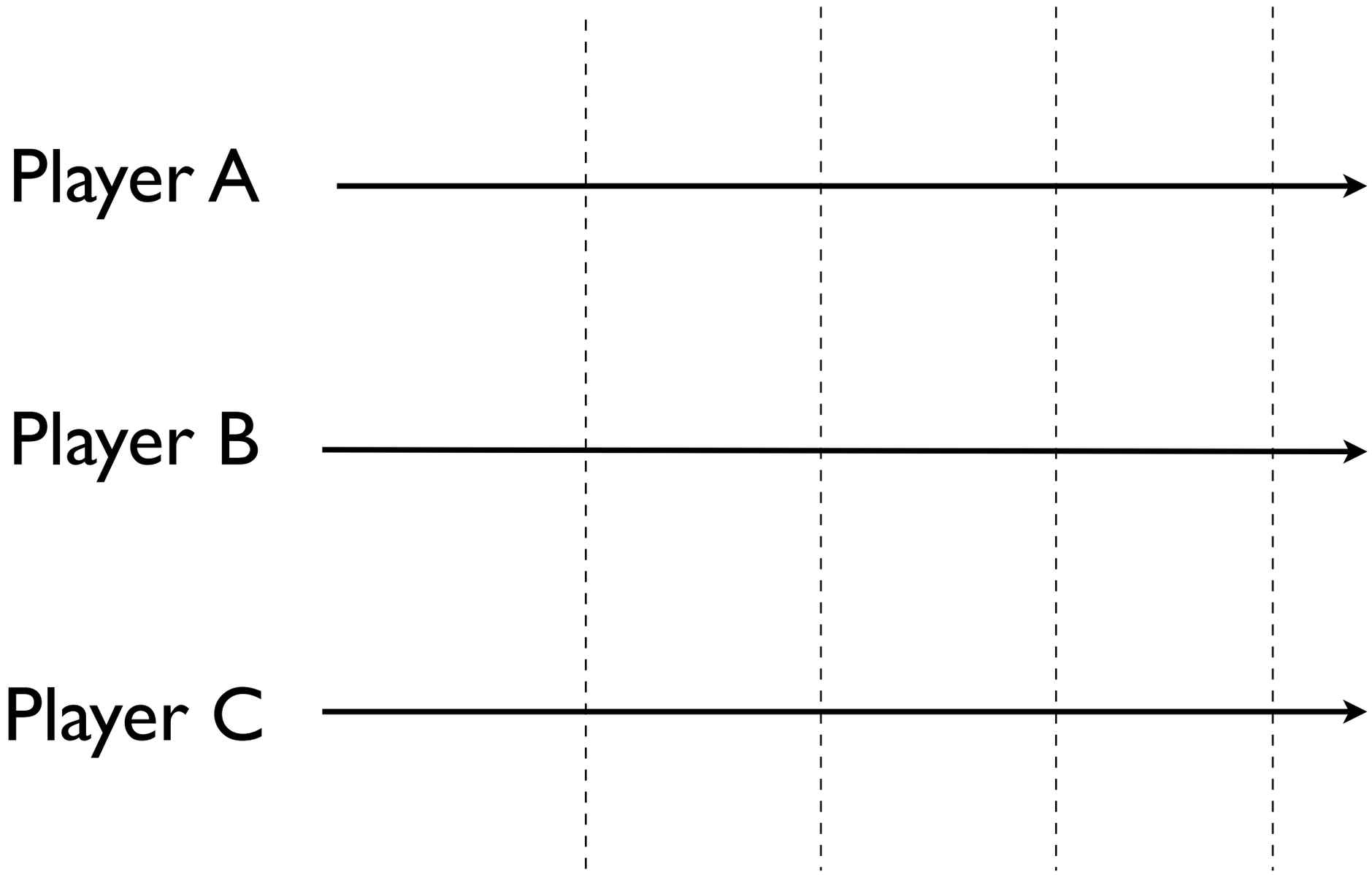
(old) **Idea**: Delay processing of messages

Bucket Synchronization

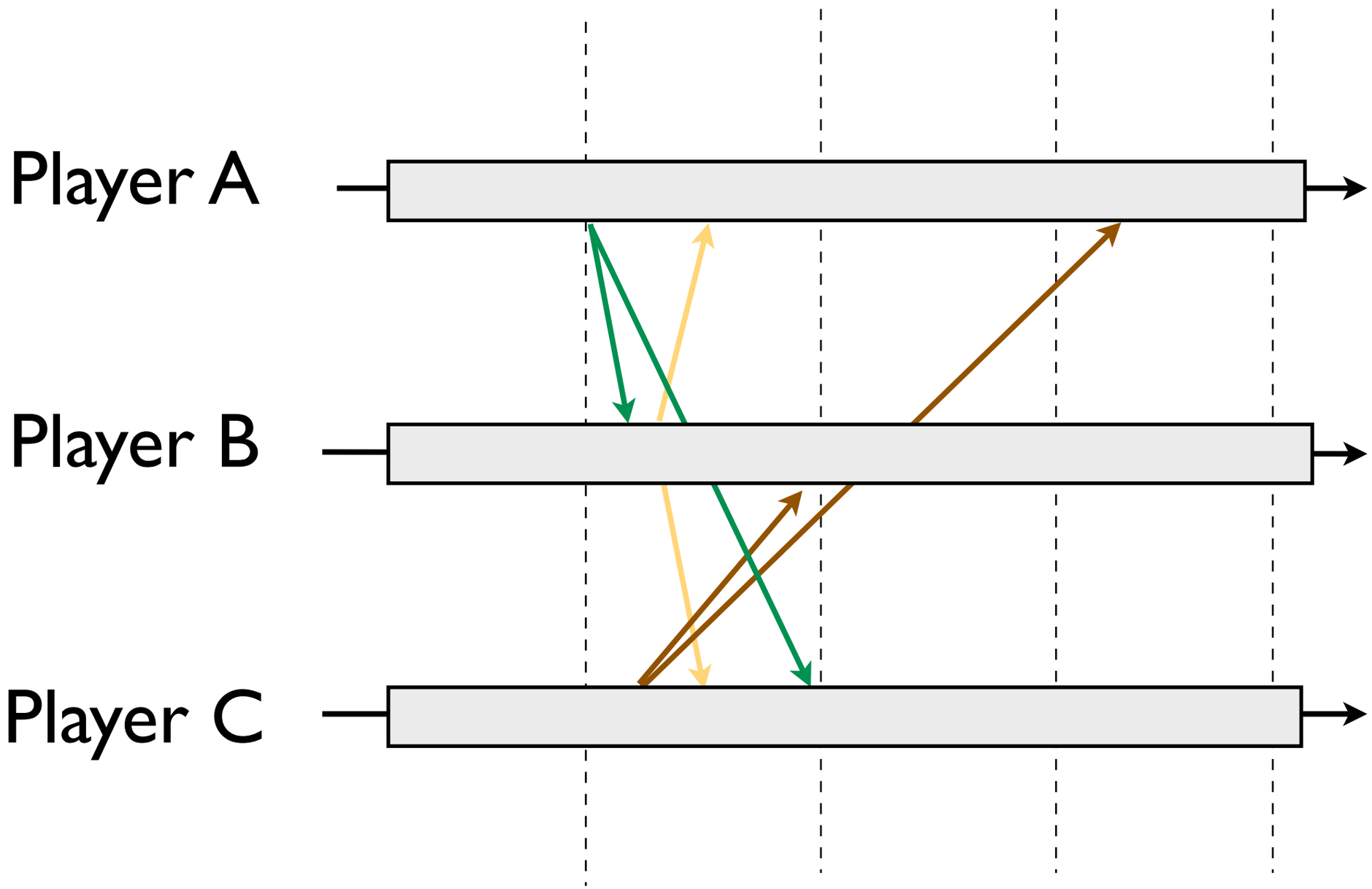
Make the game into a turn-based game ..

.. with very fast turns.

The game is divided into rounds (e.g. 25 rounds per second).

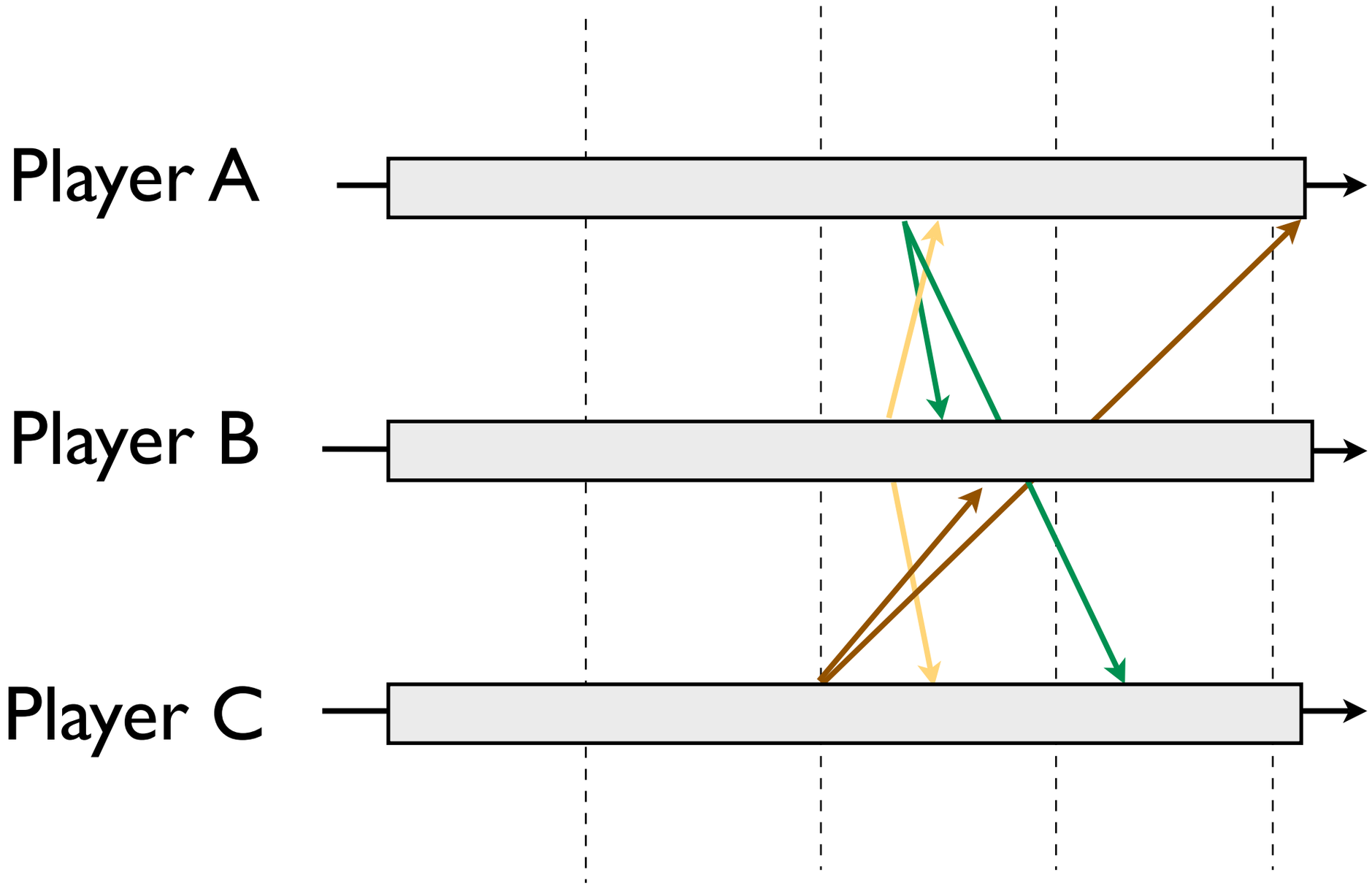


Players are expected to send an update in each round (e.g. 25 updates per second).

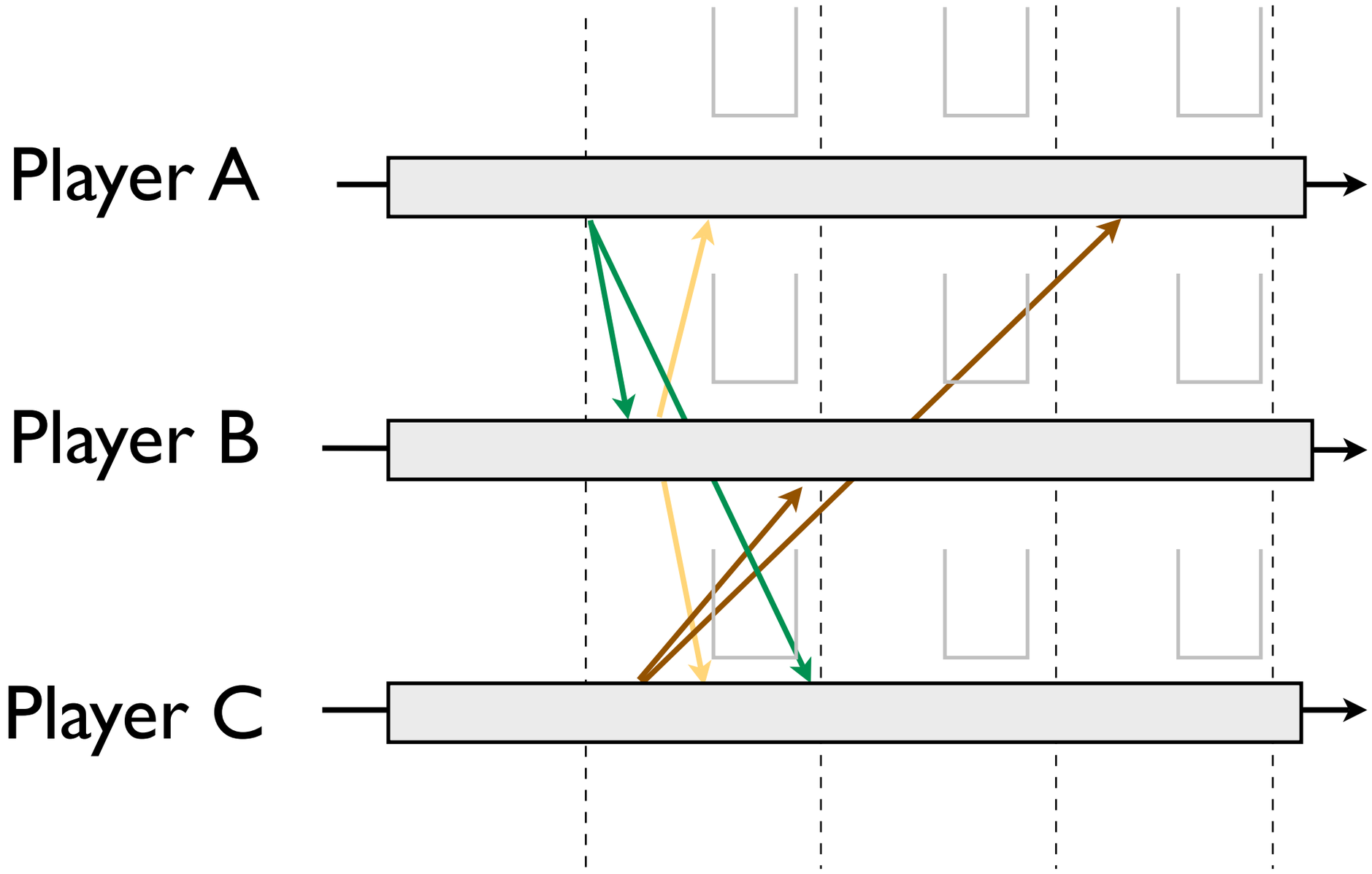


(and therefore is only suitable if we have a small number of players..)

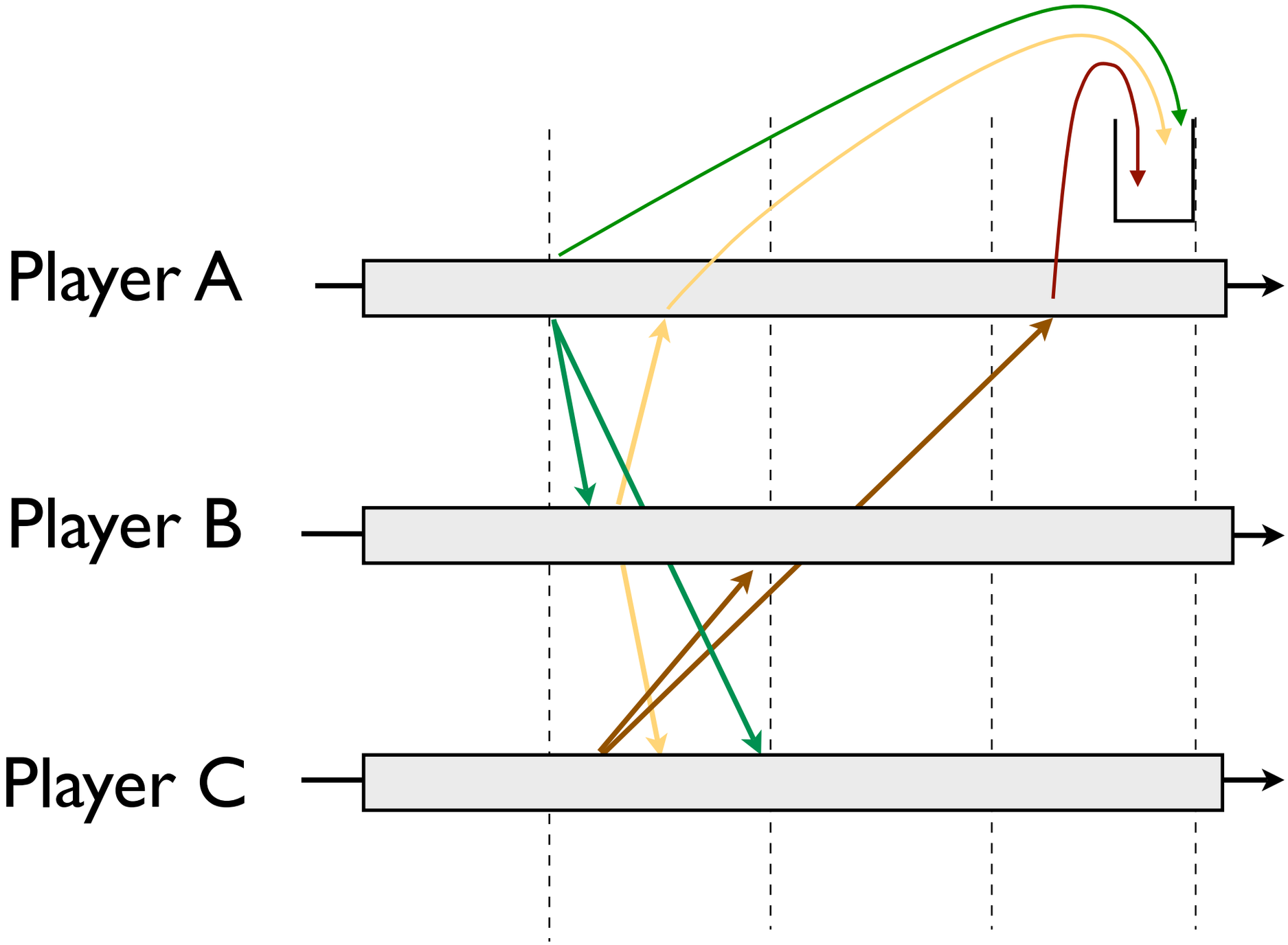
Players are expected to send an update in each round (e.g. 25 updates per second).



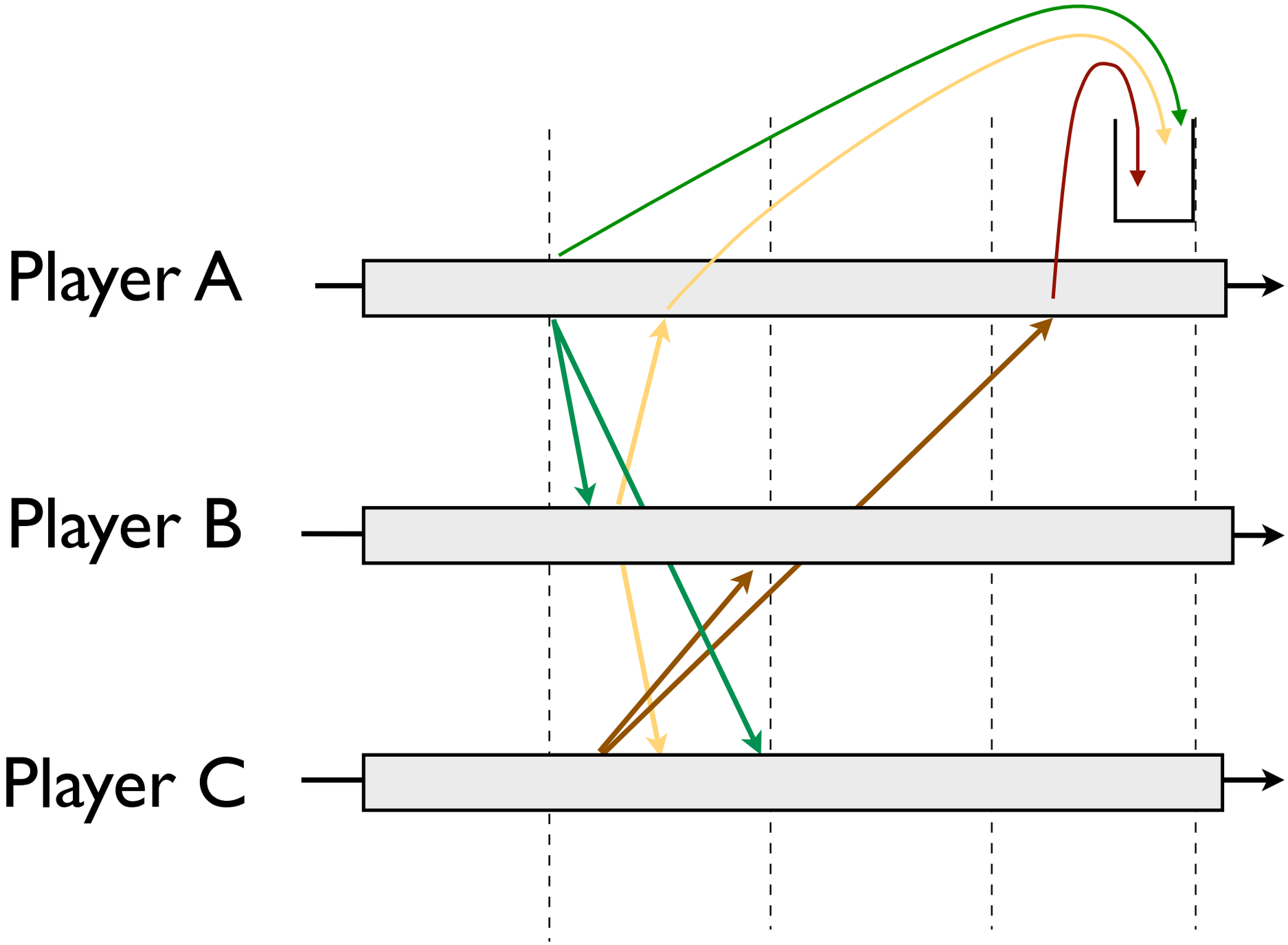
Every round has a “bucket” that collects the update messages.



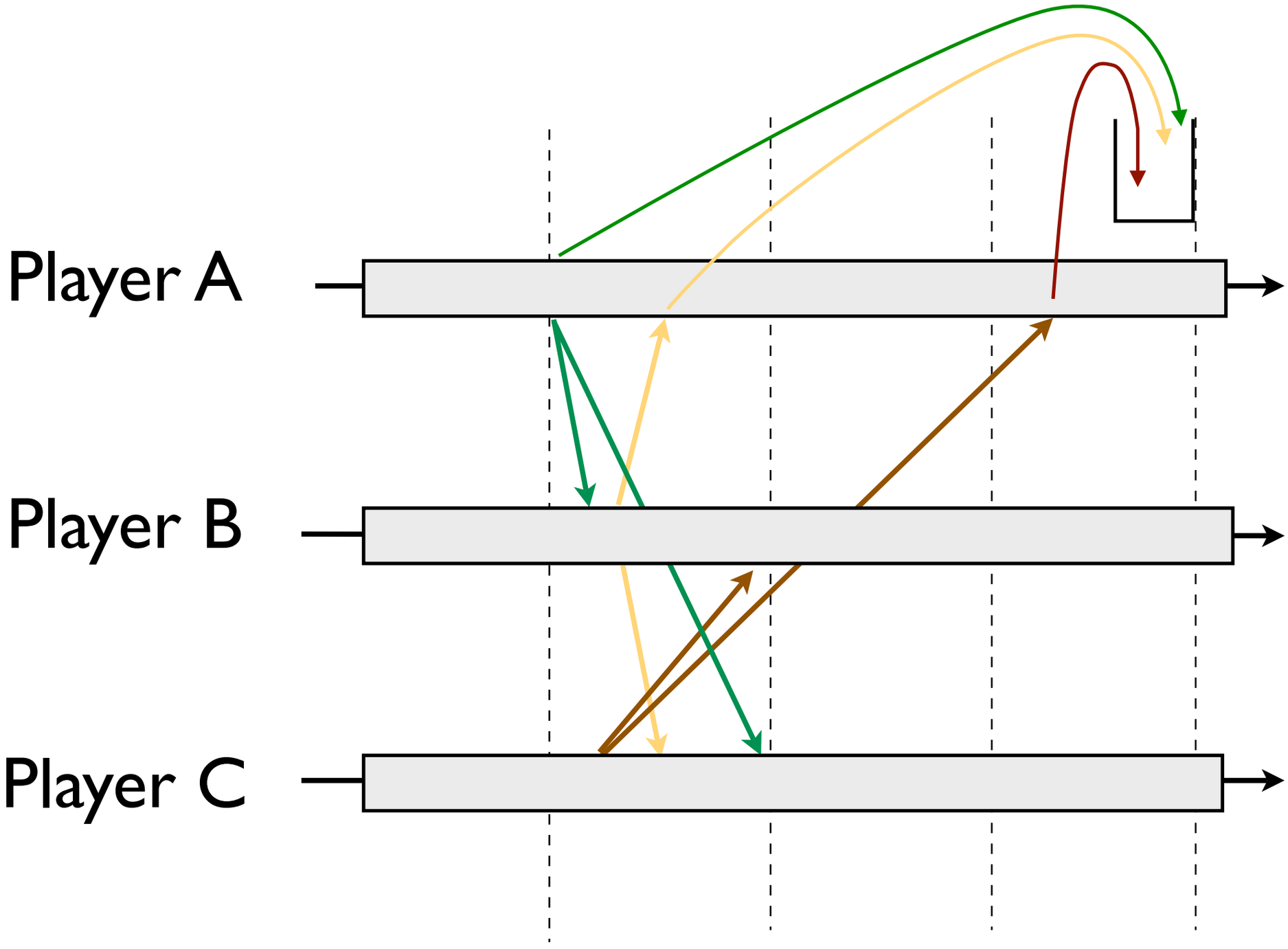
Messages generated in the same rounds goes into the same bucket of a future round.



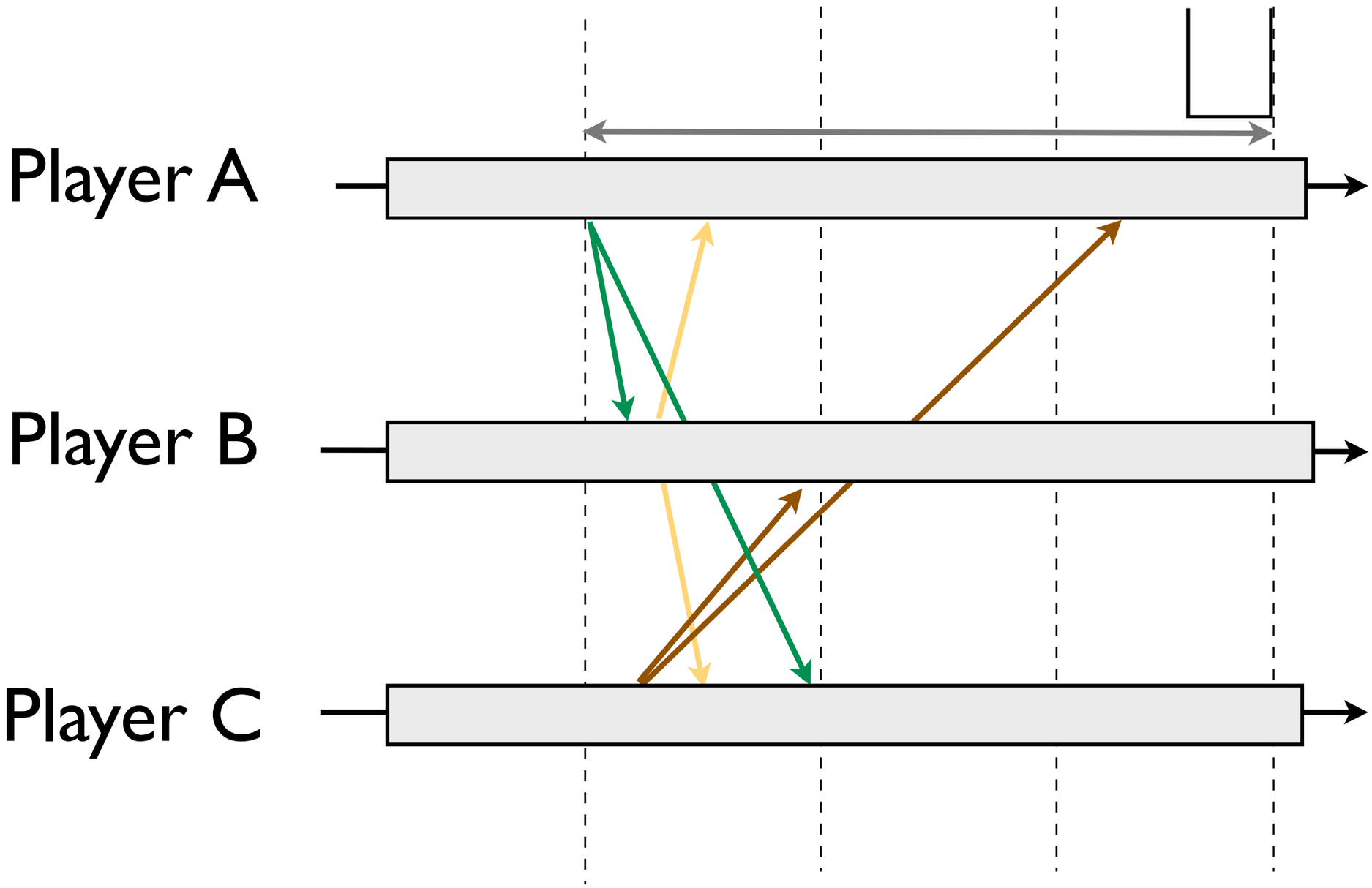
We know which rounds a message is generated based on time-stamp.



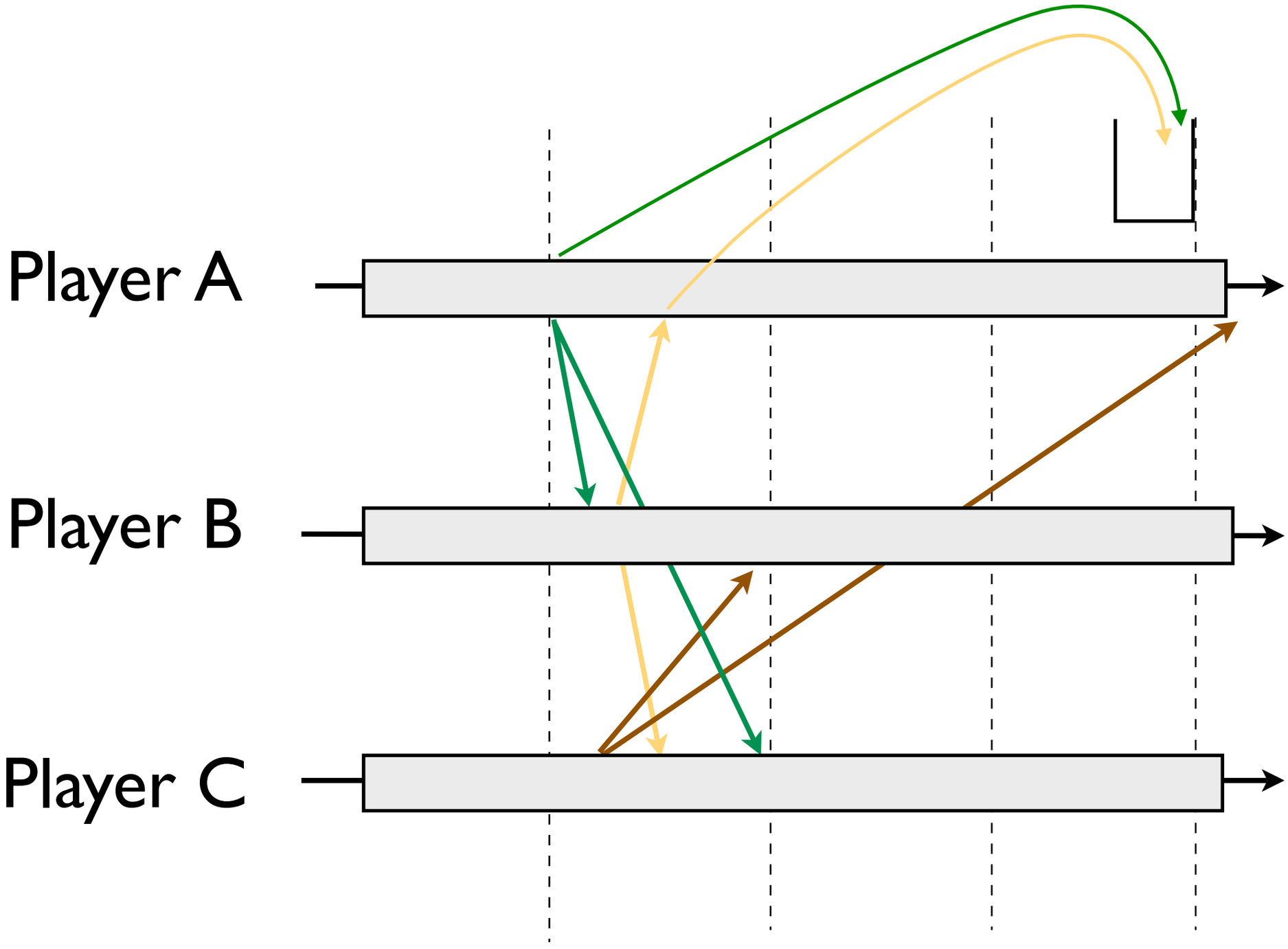
When it is time to execute a round, the messages in the bucket is processed (in order of time-stamp).



Which future bucket to go into depends on the latency among the players. (Hopefully not too far in the future else responsiveness will suffers).

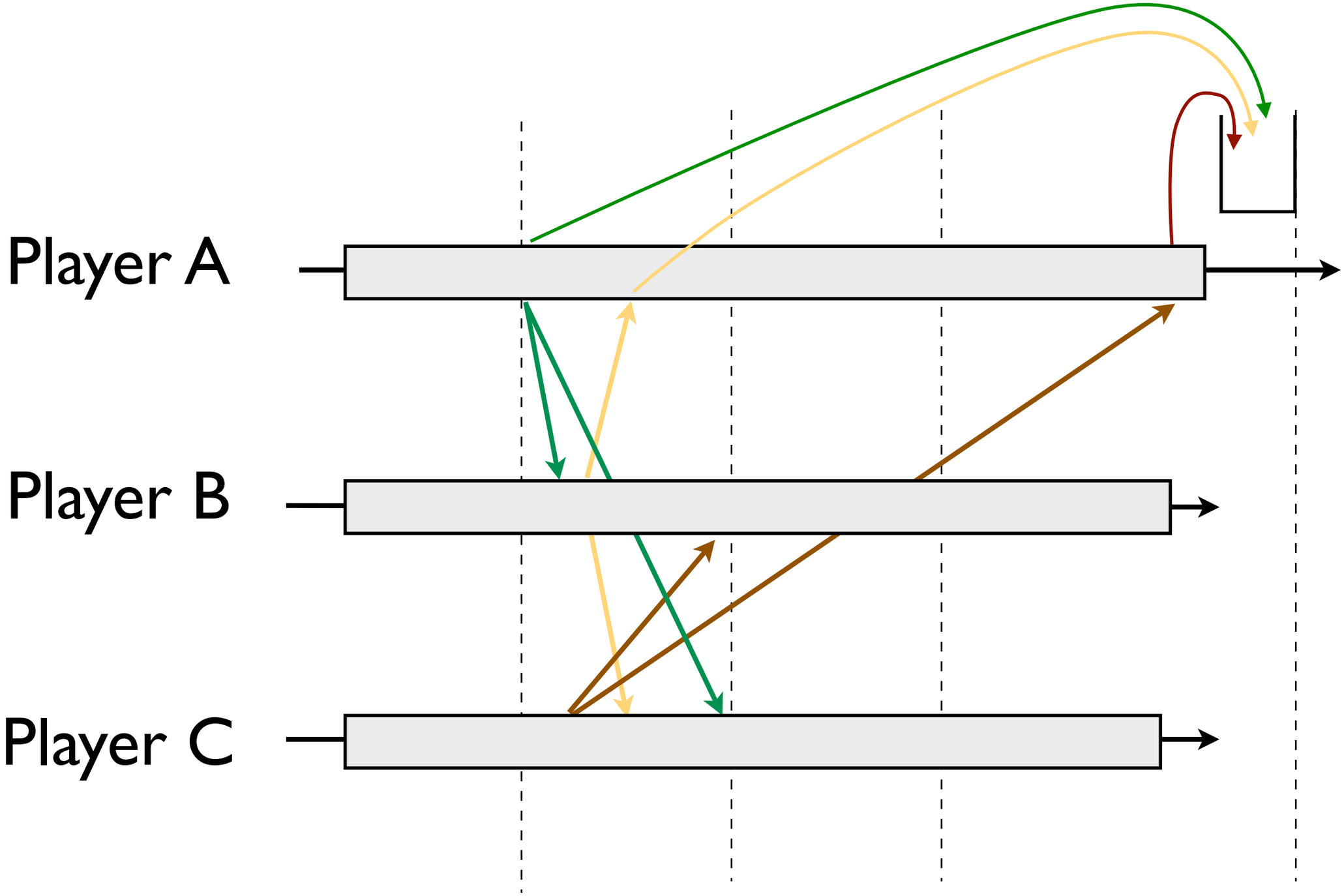


If messages from another player is lost (or late), we can predict its update (e.g. using dead reckoning) when possible.



Inconsistency still arises due to prediction.

Alternative is to ensure every update is received before executing the bucket.



Stop-and-Wait Protocol

Synchronized Simulations

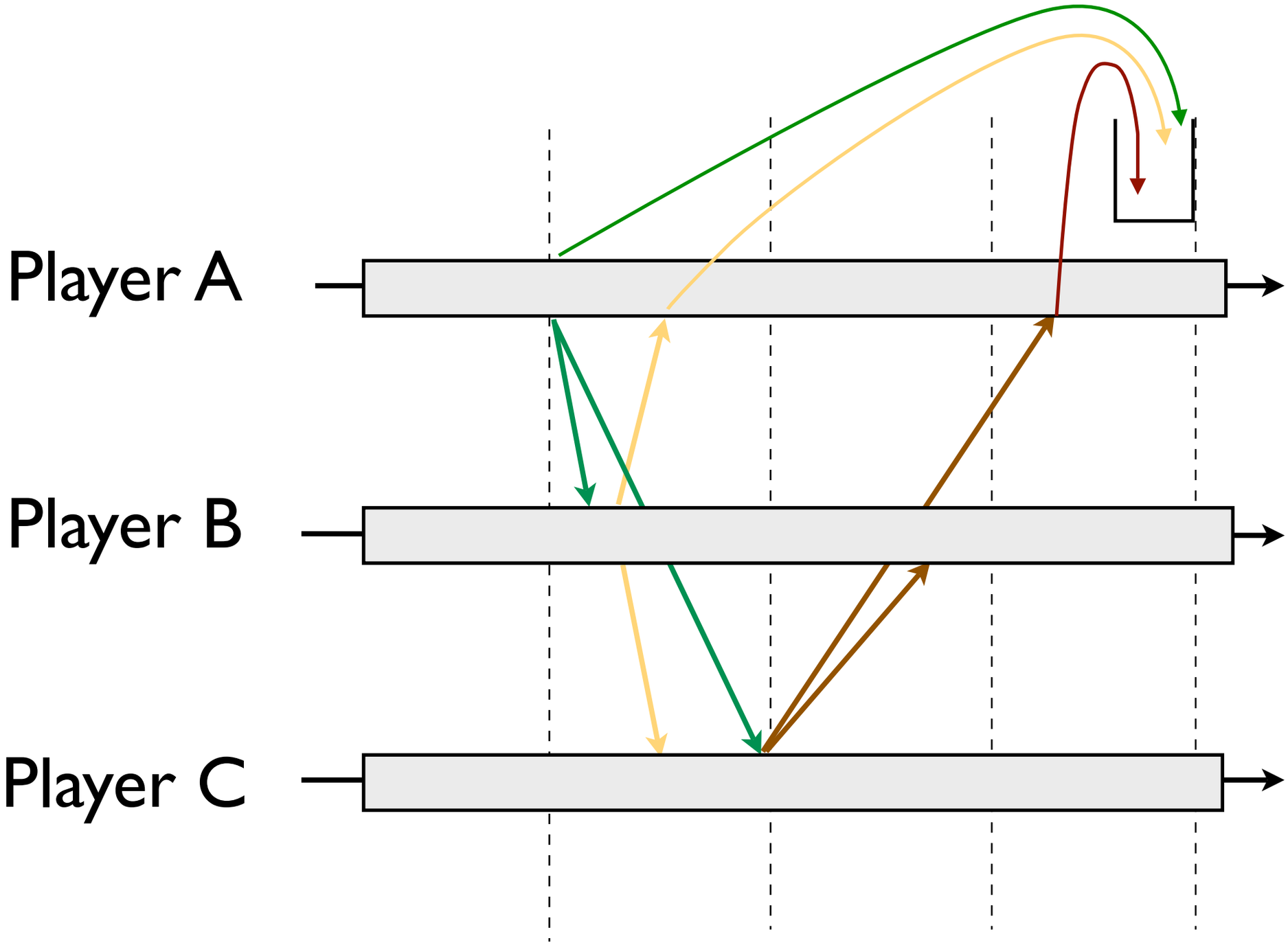
Every player sees
exactly the same states
(but maybe at different time)

Players can tell each other their processing time and latency among players, so that turn length and lag can be adjusted.

Cheating

Look-Ahead Cheat

Player C (or a bot) can peek at A's and B's actions first, before deciding his/her moves.



Dealing with cheaters:

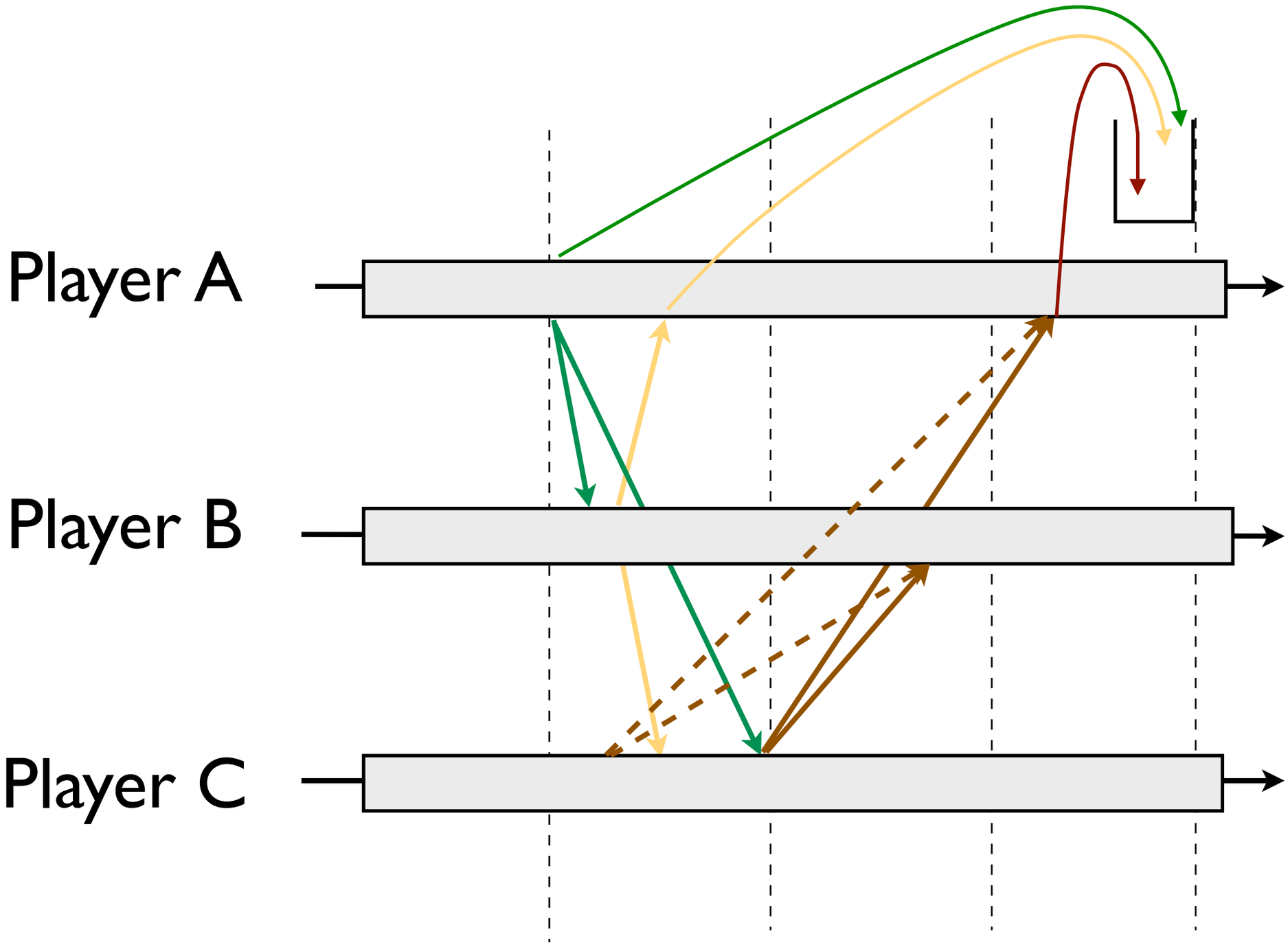
1. Prevent cheats (hard)
2. Detect cheats (easier)

Detecting Look-Ahead Cheats

“Mmm... player C always the last one that make its move”

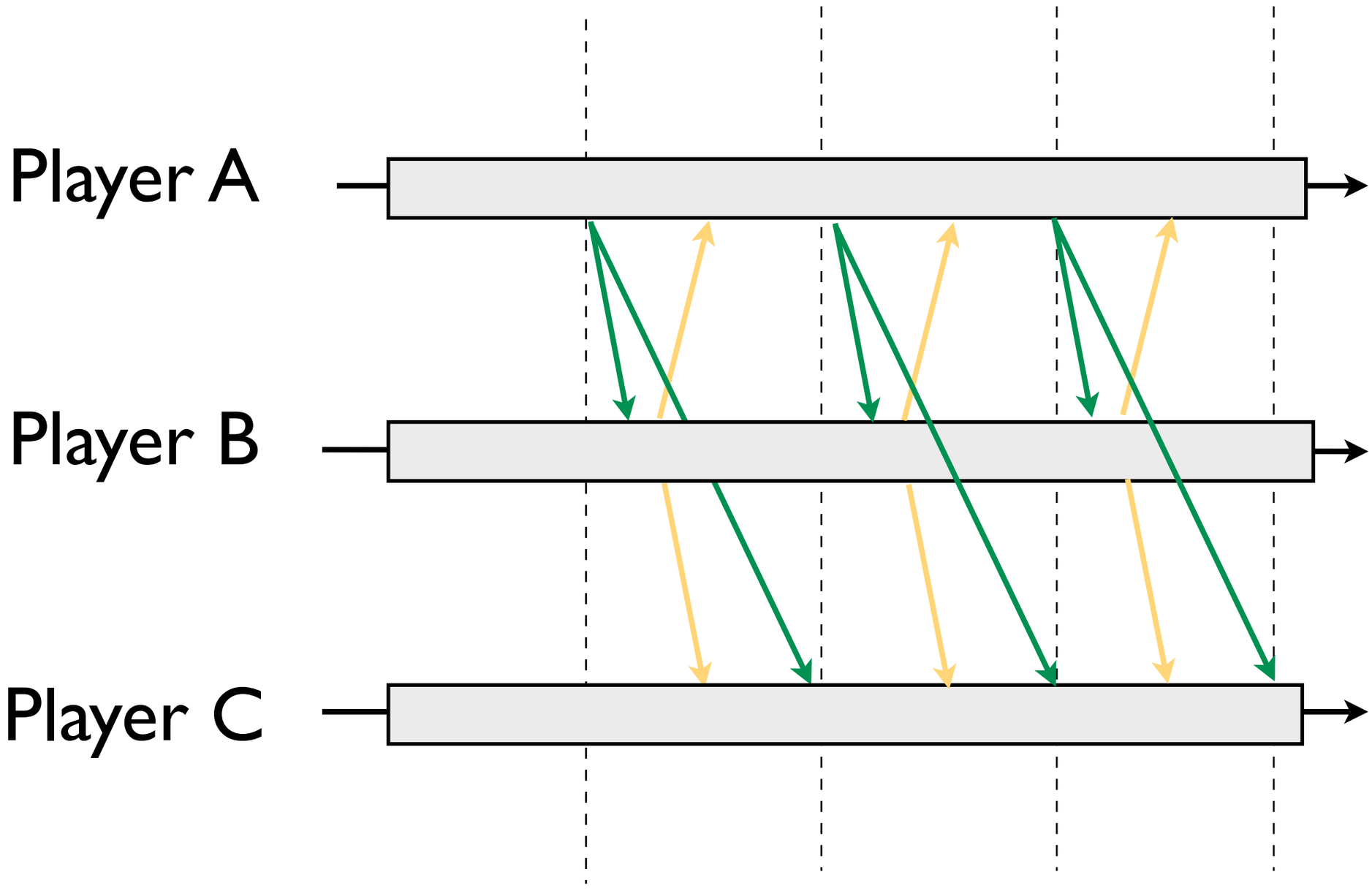
Time-stamp Cheat

Player C (or a bot) can put in an earlier time-stamp in its messages.



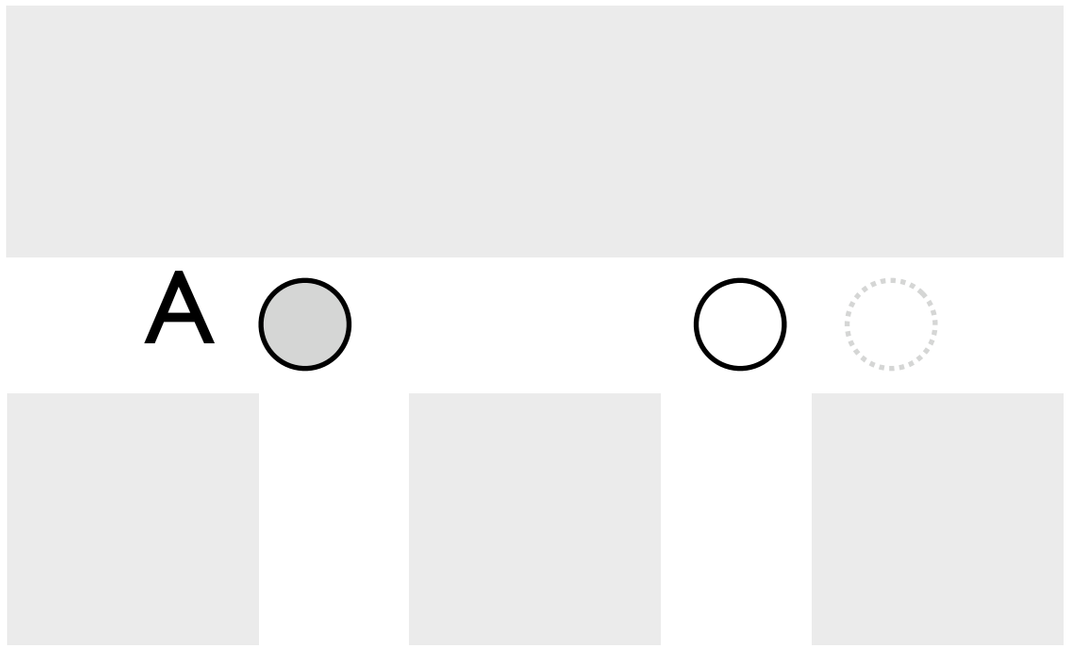
Suppress-Update Cheat

If dead reckoning is used, Player C can stop sending update and let others predict its position. C then sends an update at appropriate time to "surprise" other players.

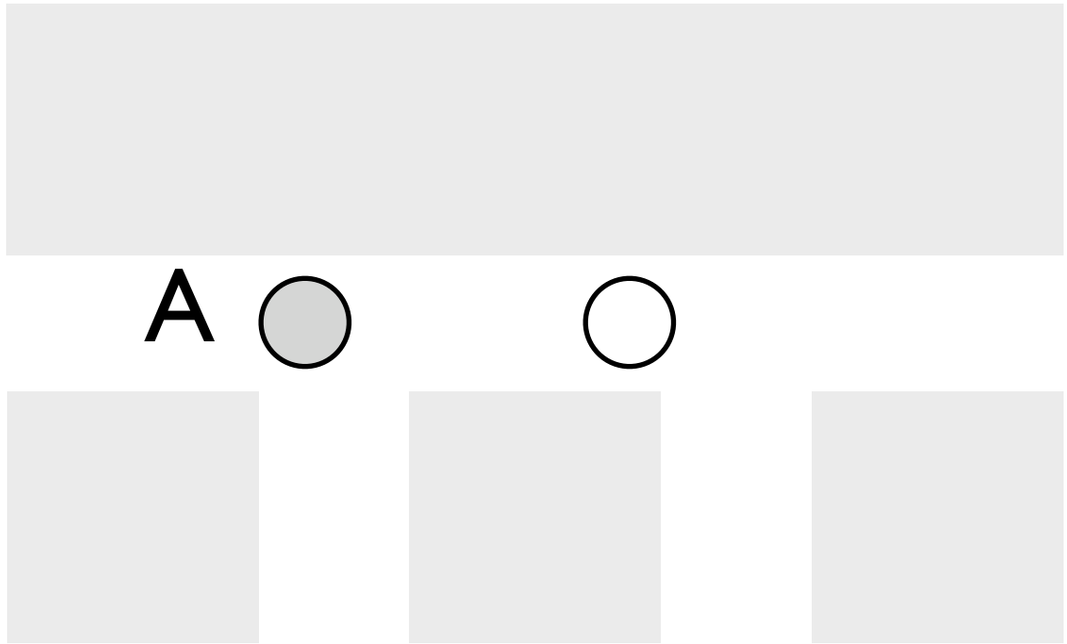



A
C

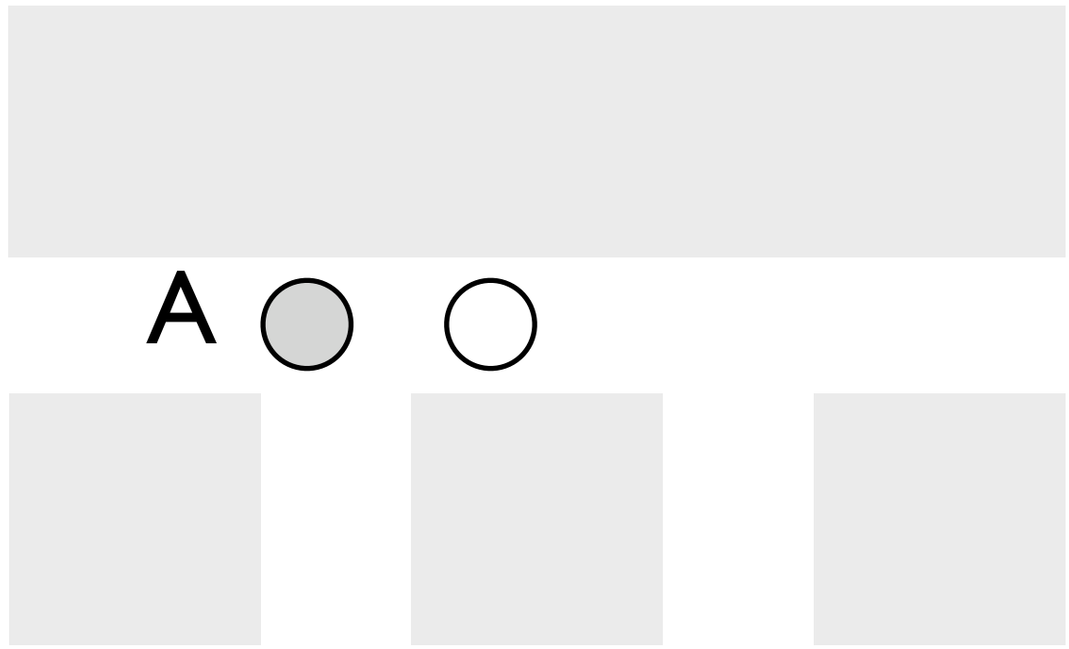
C stops sending update.
A predicts C's position.



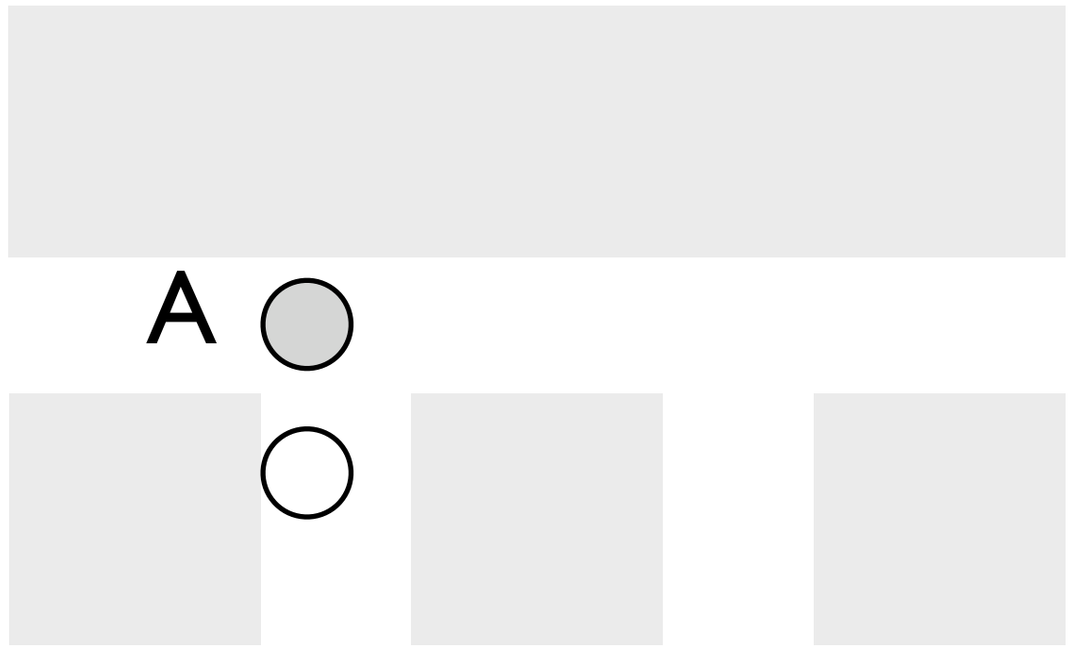
C stops sending update.
A predicts C's position.



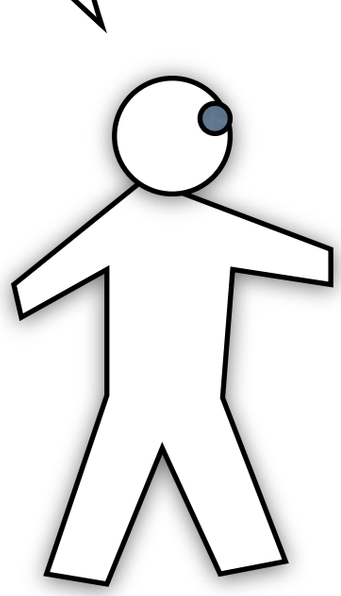
C stops sending update.
A predicts C's position.



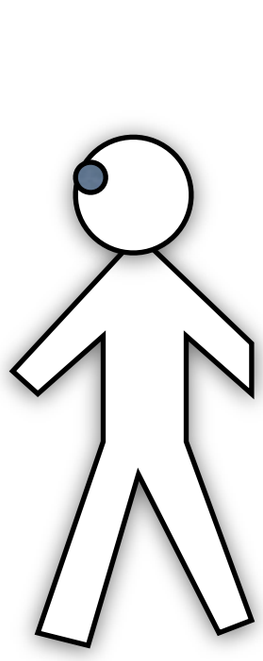
C sends an update and shoots A.



Cheater!



Not me! My packets were dropped..



Cheat-Proof Protocol

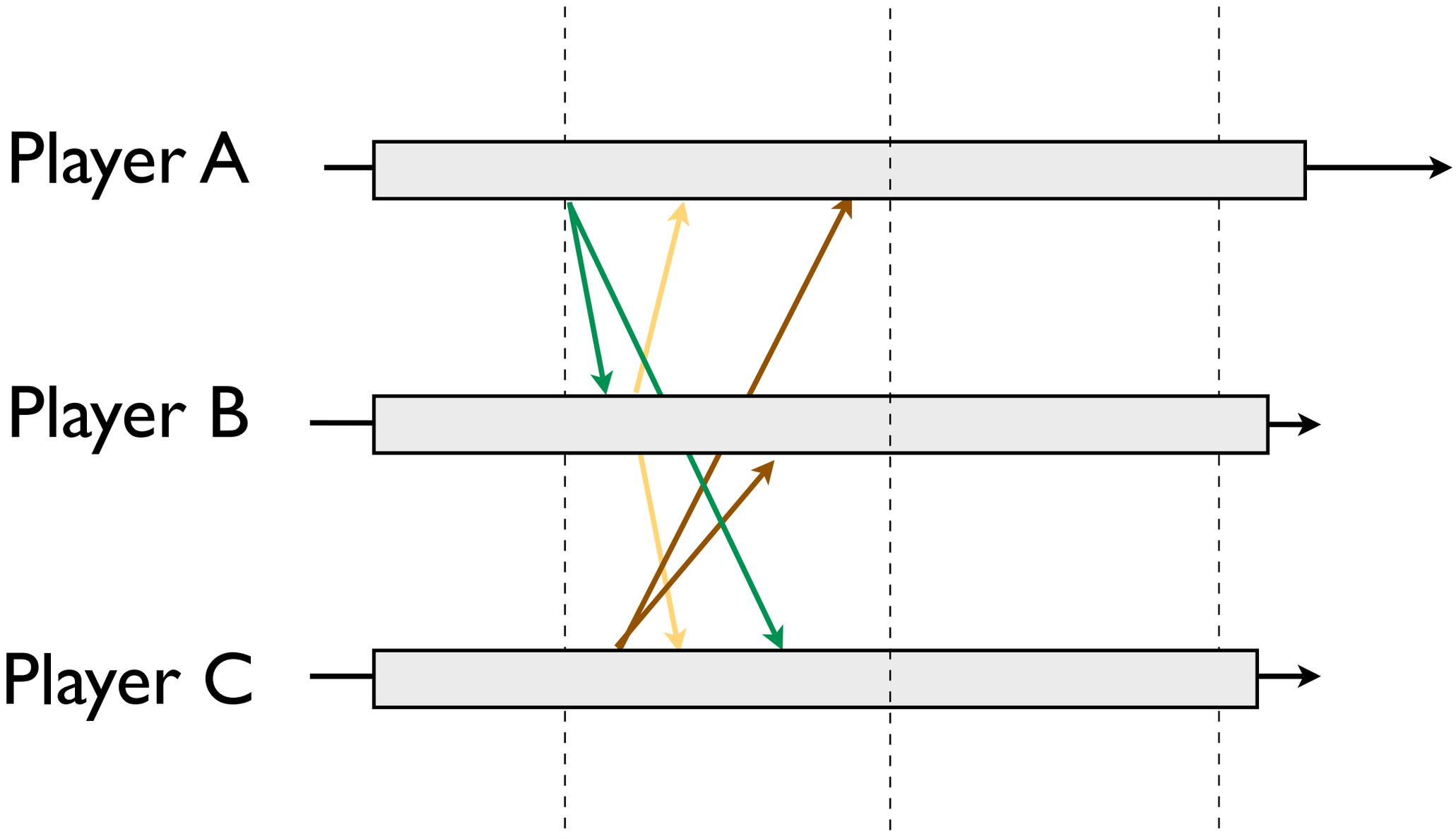
Lock Step Protocol

One-Way Function f:
Given x, we can compute f(x) easily. Given f(x) it's hard to find out x if x is random.

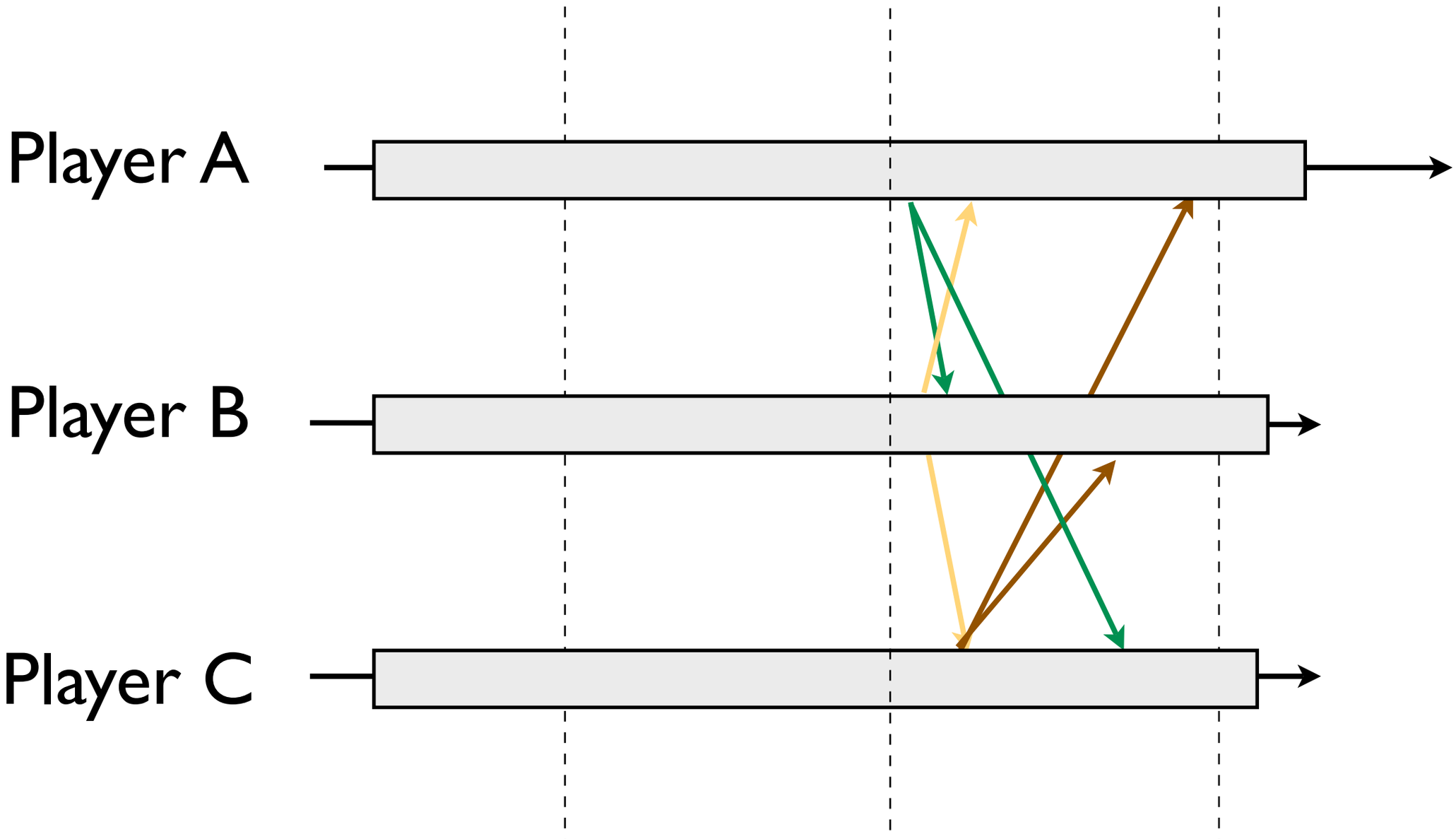
Lock Step Protocol

Two stages needed for each round of stop-and-wait updates.

Stage **1**. Everyone decides on its move x, and send f(x) to each other.



Stage **2**. After f(x) from every other player is received, sends x to each other.



How does lock-step prevent:

look ahead cheat?
timestamp cheat?
suppress-update cheat?

f(x) is known as commitment to x.

A player, once committed to its move, can't change it.

Problem: Lock-step protocol is slow.

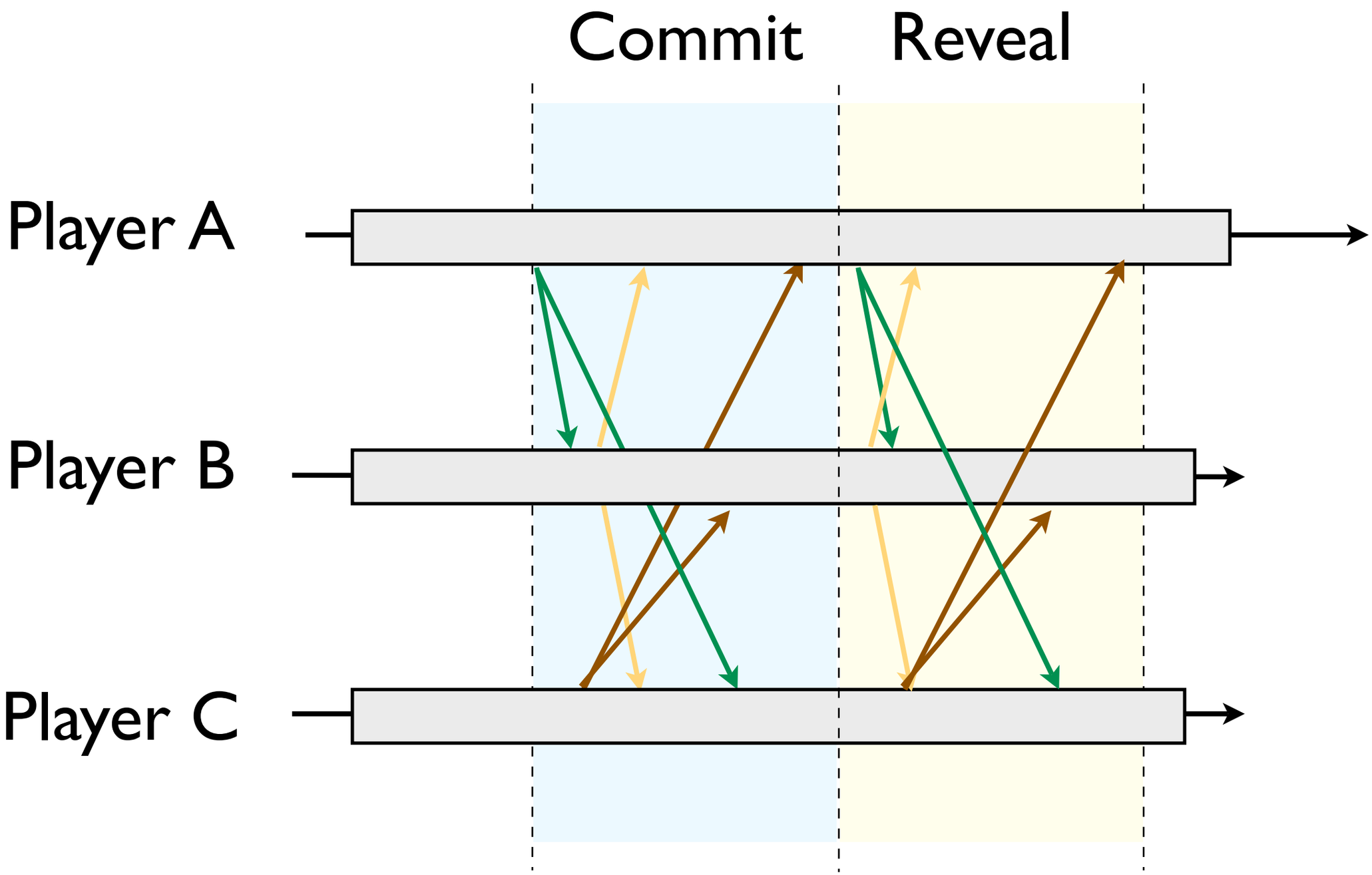
Idea: Use Interest Management

Players only engaged in lock-step protocol when they influence each other. Otherwise their games proceed independently.

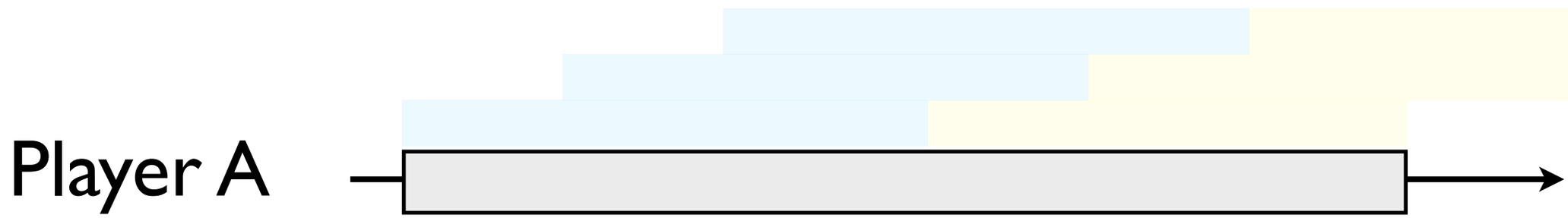
This is known as

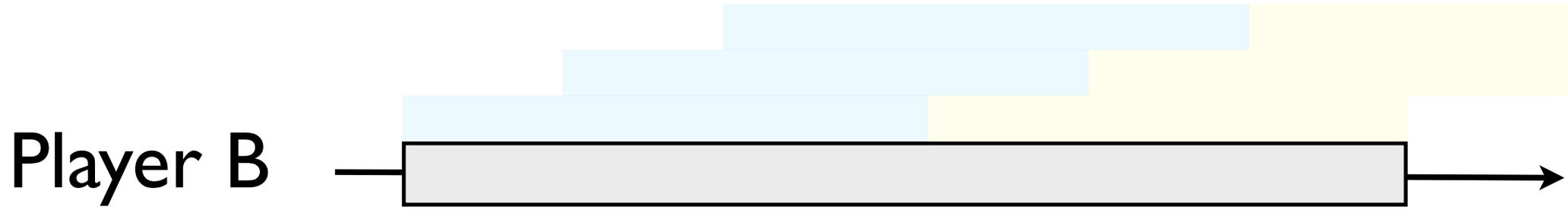
Asynchronous Synchronization or Asynchronous Lock-step

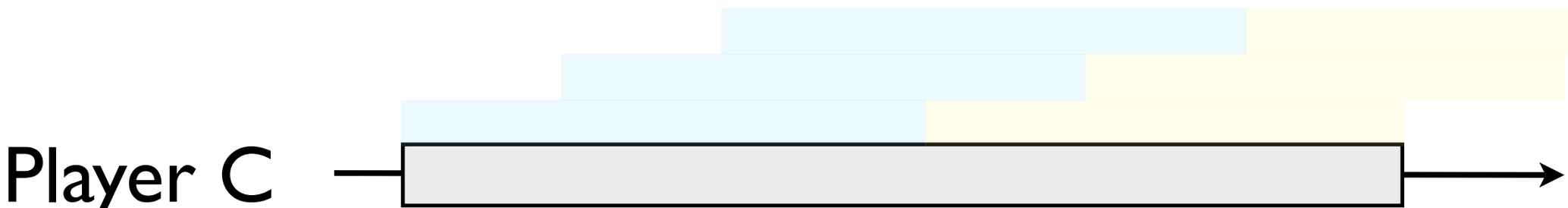
Let's call the two stages in lock-step protocol as commit and reveal stages.



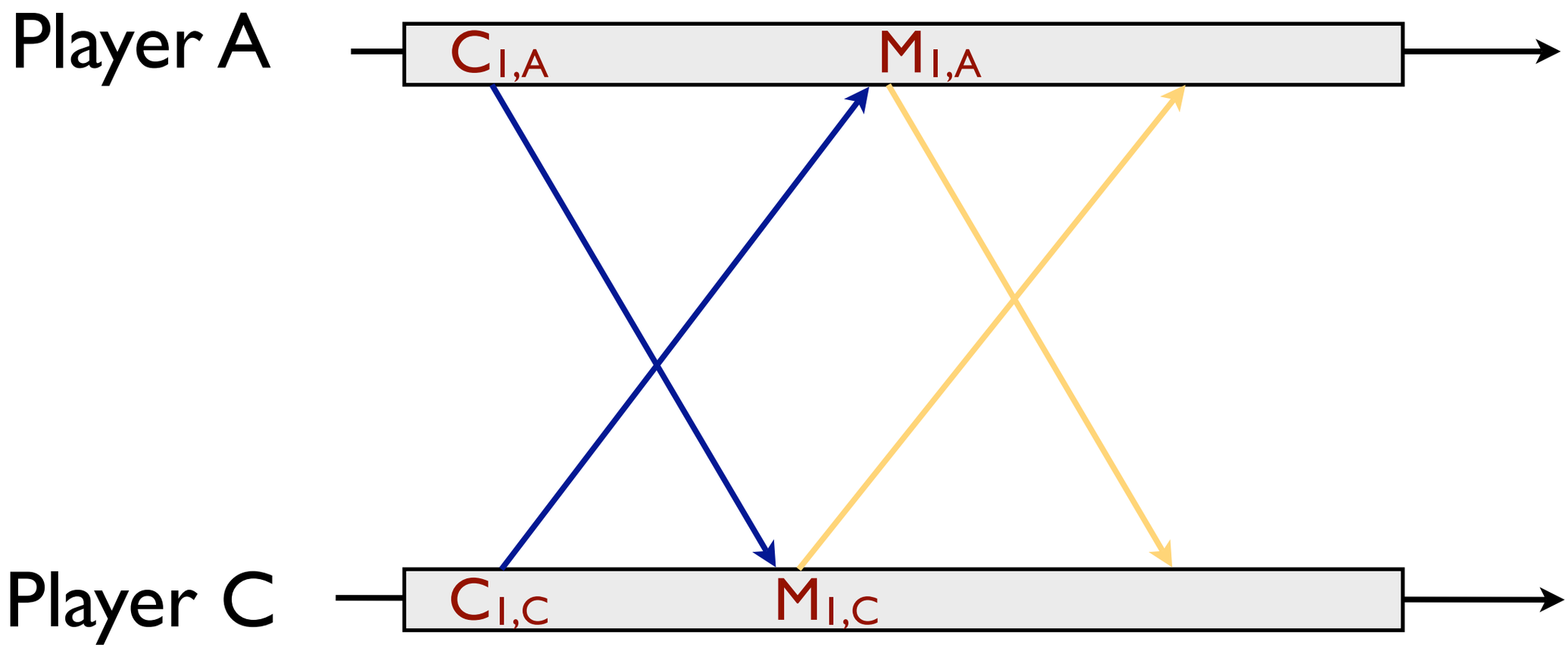
We may also stagger these two stages to improve responsiveness. Multiple commitments can be sent out before we reveal the actions.



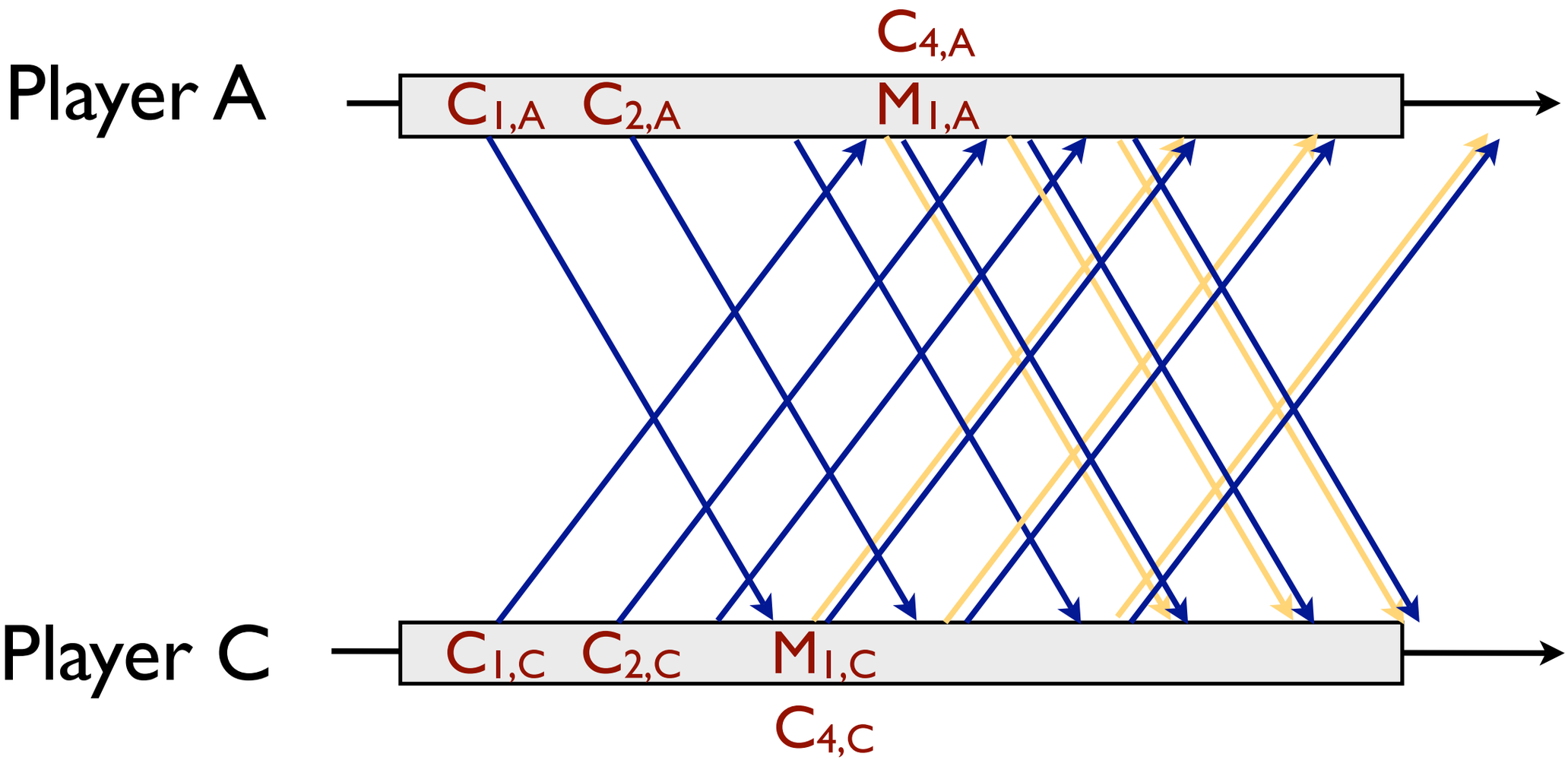




1. A player can reveal its action in round i once it receives all commitment of round i from other players.



2. A player can make p moves (send p commitments) without engaging in lockstep.



This is known as

Pipelined Lock-step

l_{max} = maximum latency
r_{max} = maximum frame (round) rate

Lockstep Protocol

$$1/r = \max\{2l_{max},\ 1/r_{max}\}$$

l_{max} = maximum latency
r_{max} = maximum frame (round) rate

Pipeline Lockstep Protocol

$$1/r = \max\{2l_{max}/p,\ 1/r_{max}\}$$

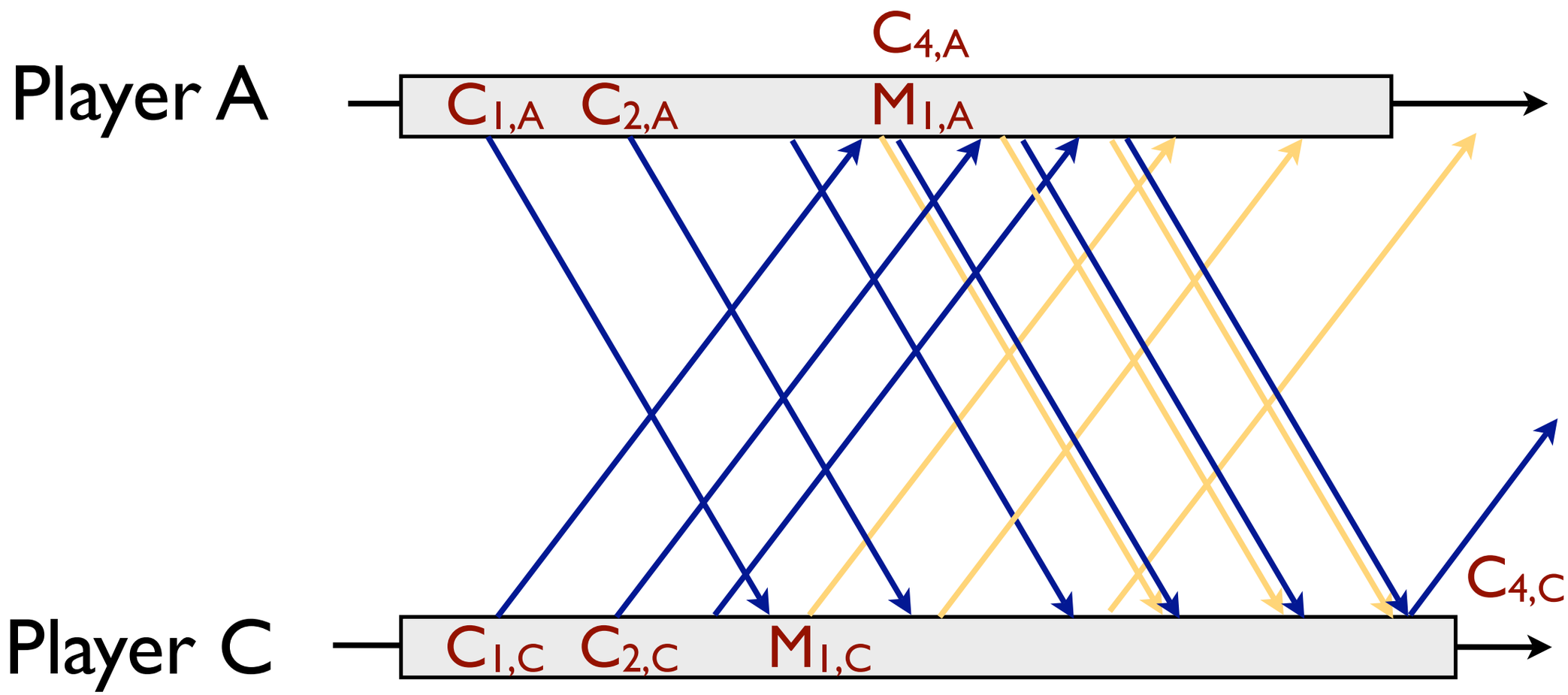
l_{max} = maximum latency
r_{max} = maximum frame (round) rate

We can pick optimal p as

$$p = 2\ l_{max}\ r_{max}$$

Cheating in Pipelined Lock-step

C makes its 4-th move after seeing the first p moves from A. A's first six moves is not based on C's move.



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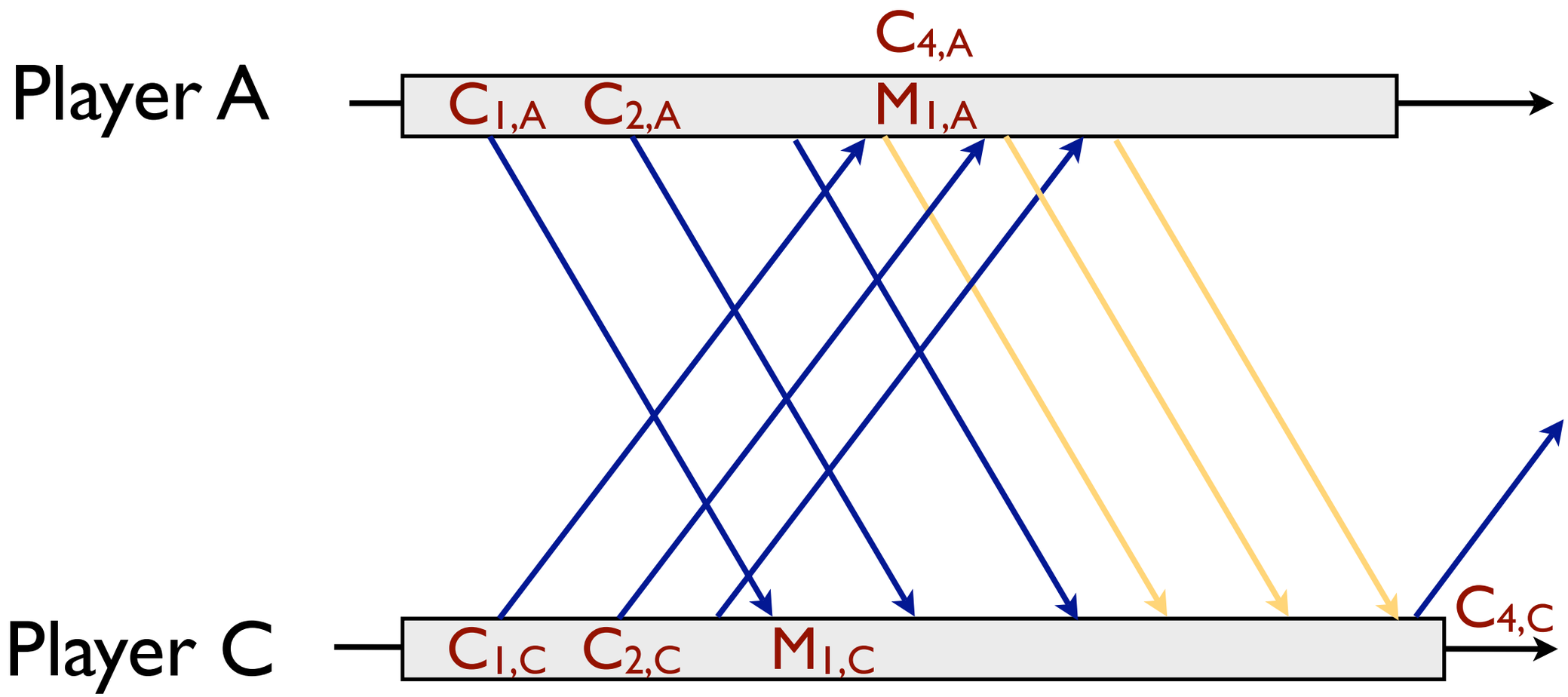
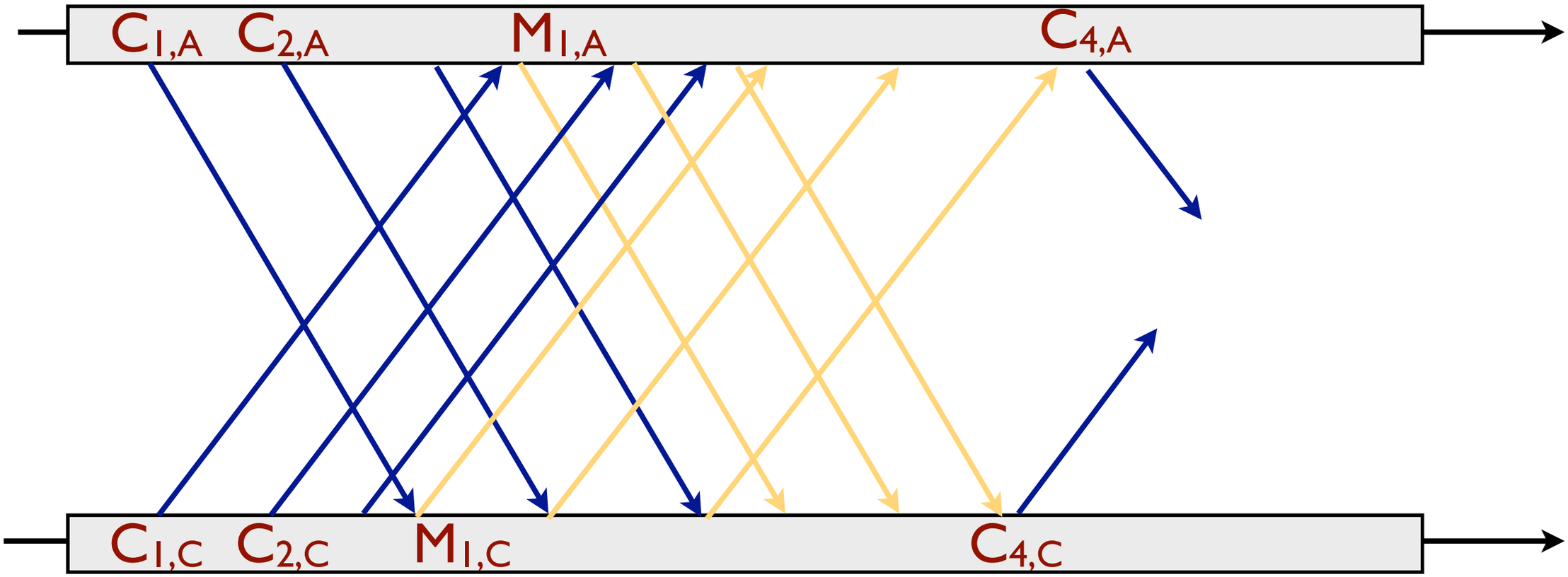
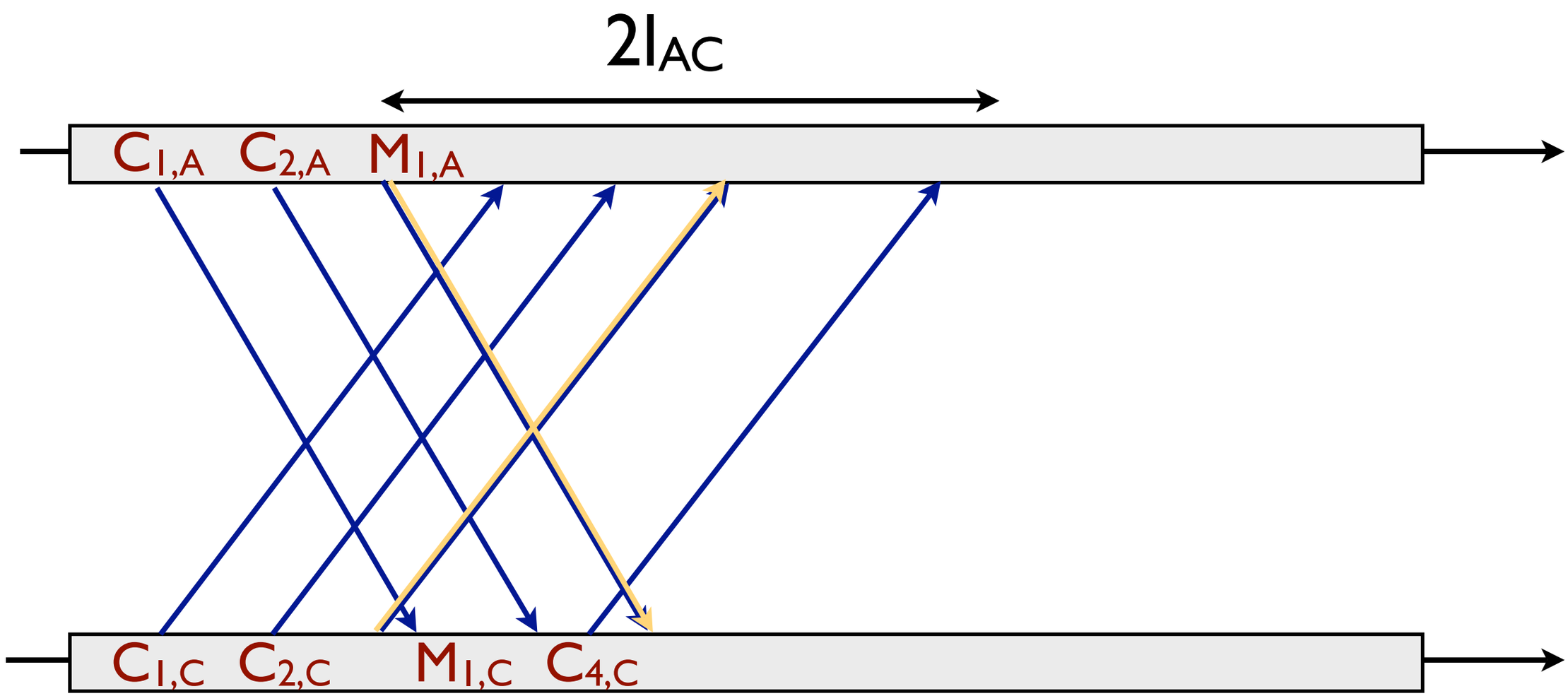


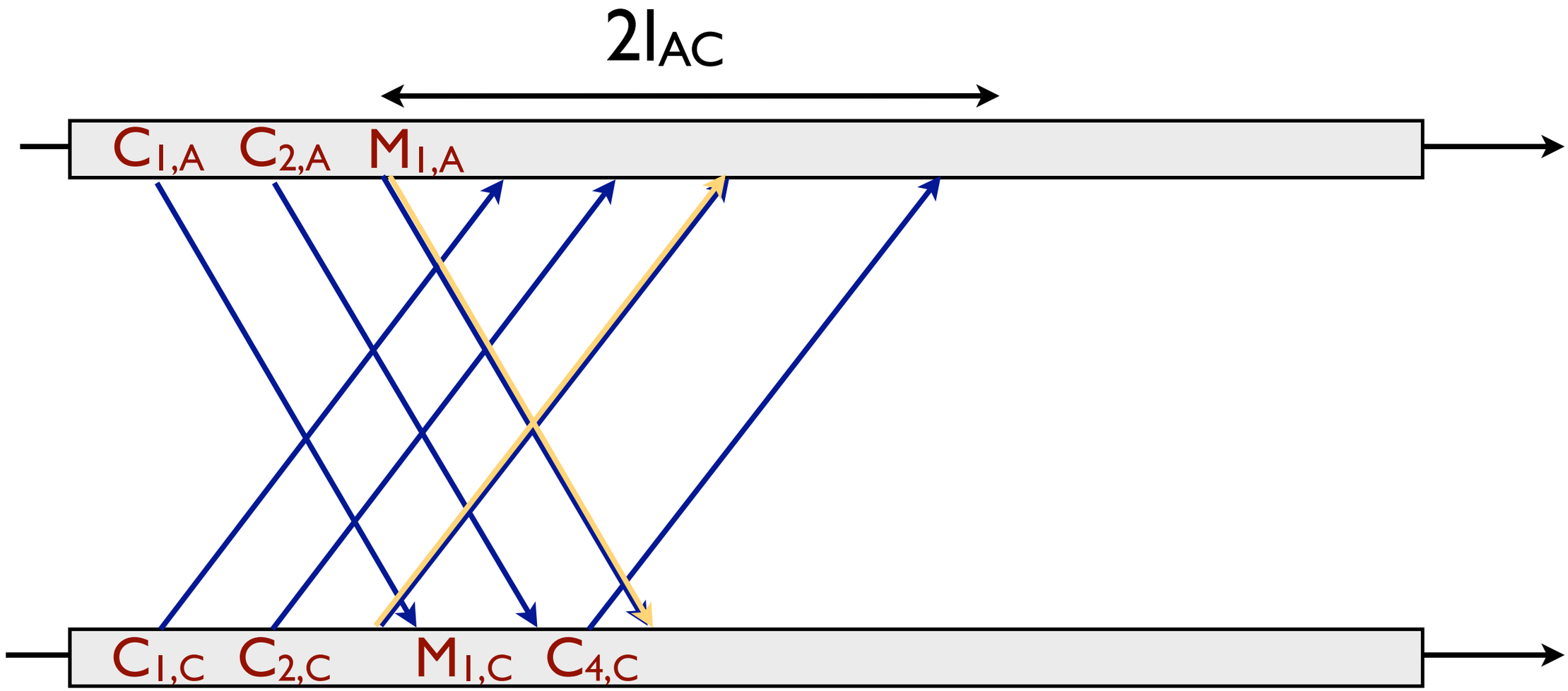
But it's fair if all players do the same.



Player C can't peek at extra moves if $C_{4,C}$ is received within $2l_{AC}$ of sending $M_{1,A}$



We can detect late commit if we know the latency between players.



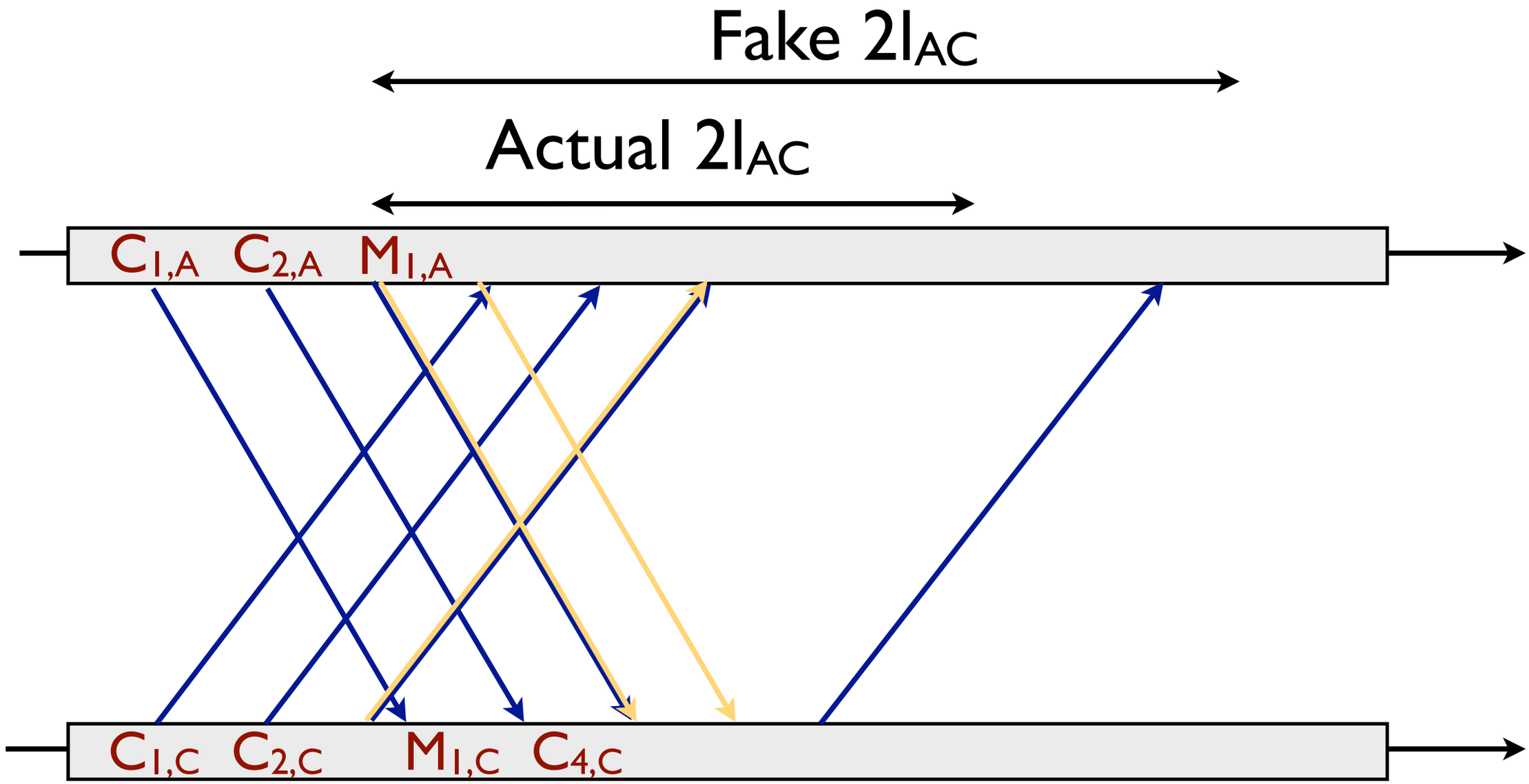
l_{max} = maximum latency
r_{max} = maximum frame (round) rate

Pipeline Lockstep Protocol (without late commit)

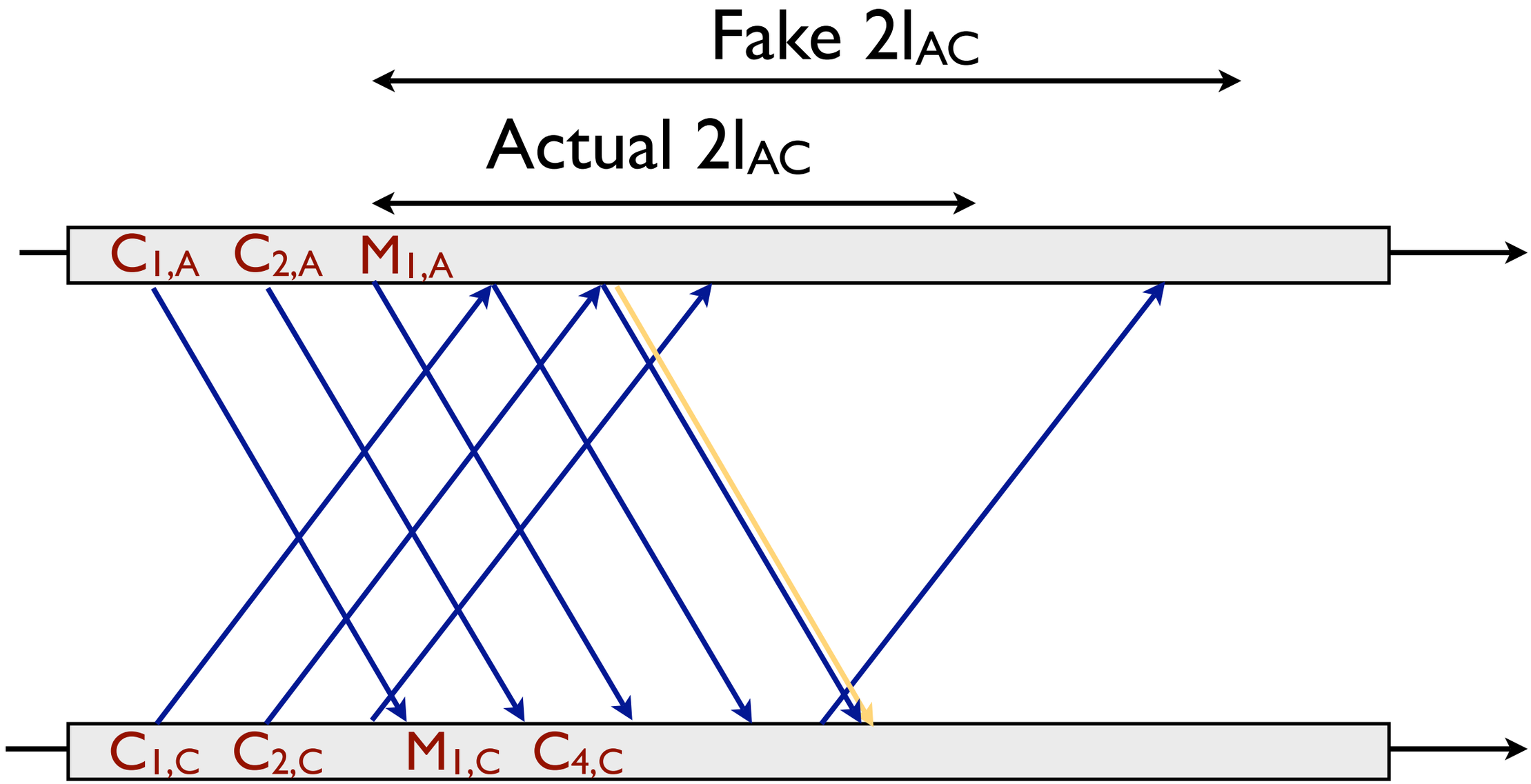
$$l/r = \max\{l_{max}/p,\ l/r_{max}\}$$
$$p = l_{max}\ r_{max}$$

Player can lie about latency!

C can pretend to be on a slow network when measurement of l_{AC} is done (e.g. using ping).



If fake l_{AC} is larger than l_{max} , then we increase p, limiting the cheat to one round.



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