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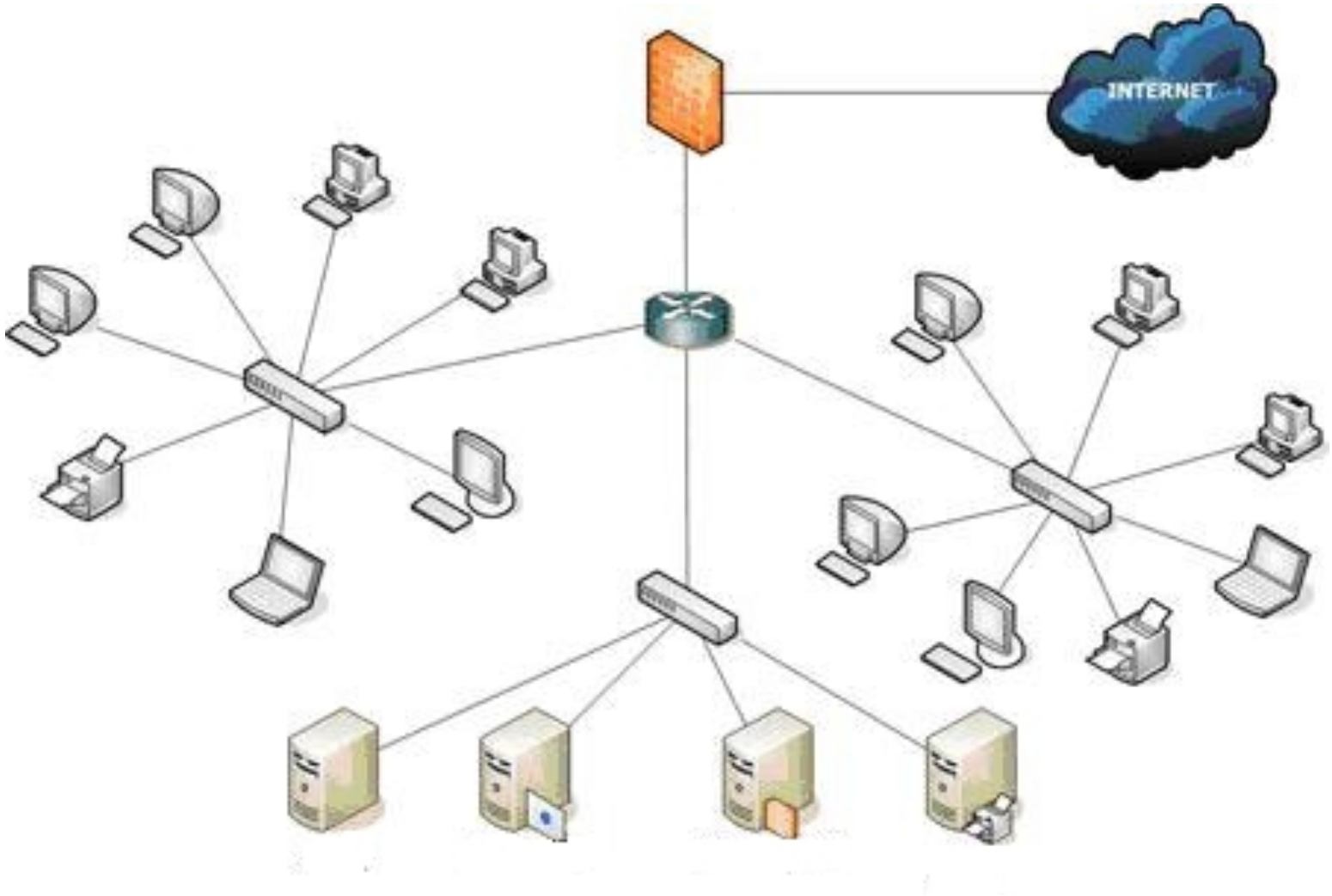
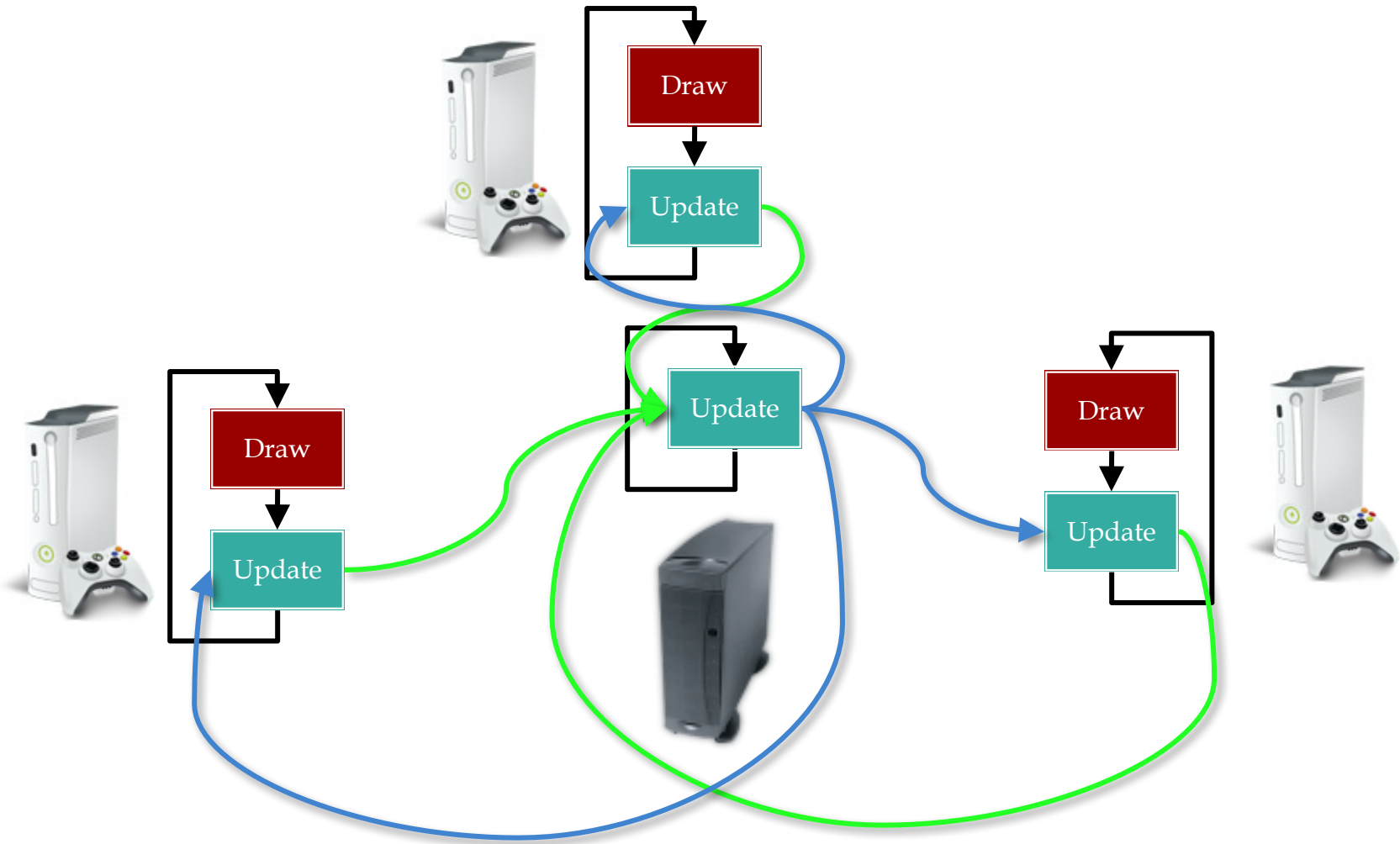
Lecture 30

# Networking: Consistency

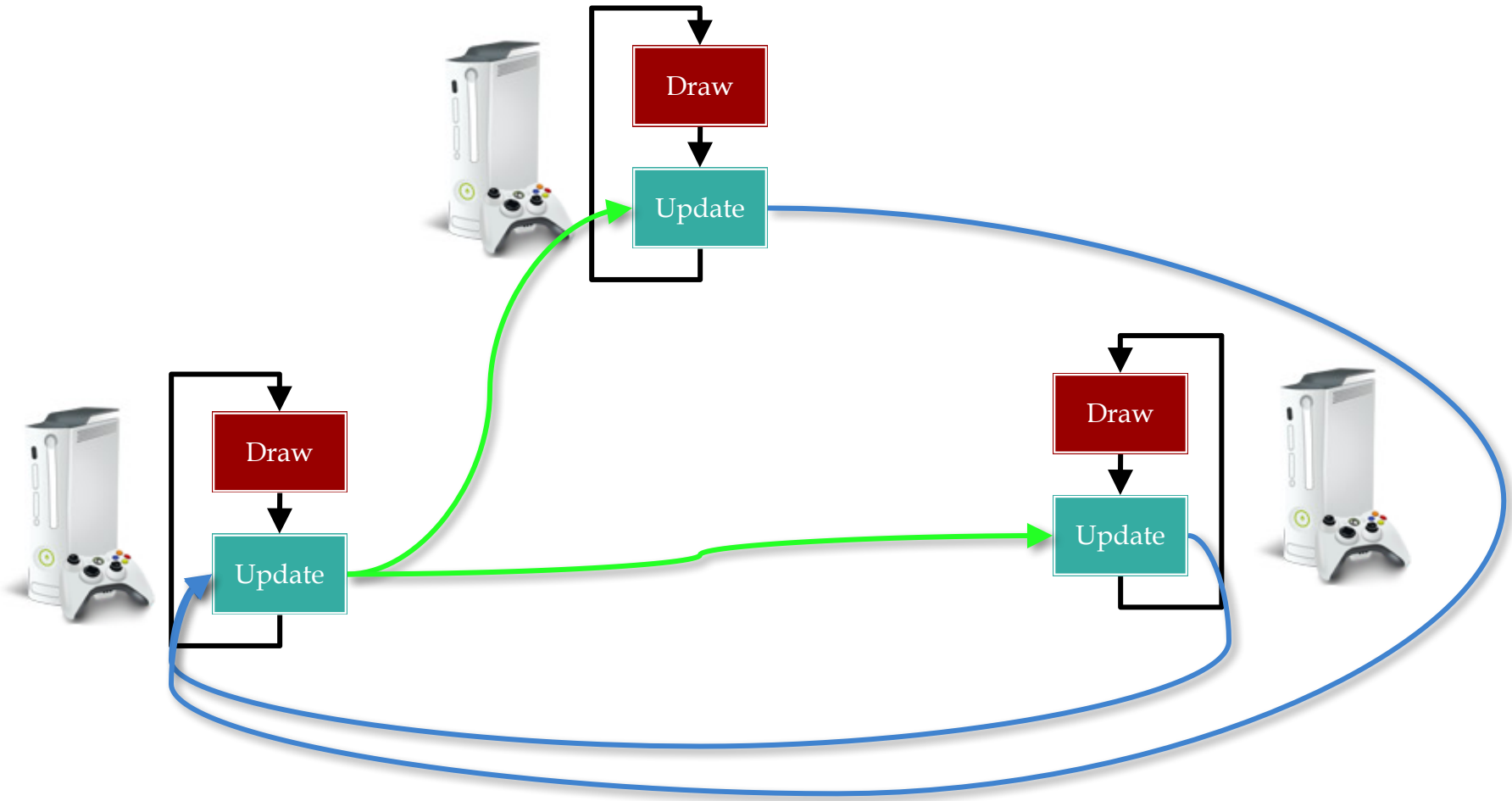
# Why Network Games?



# Architecture: Client-Server

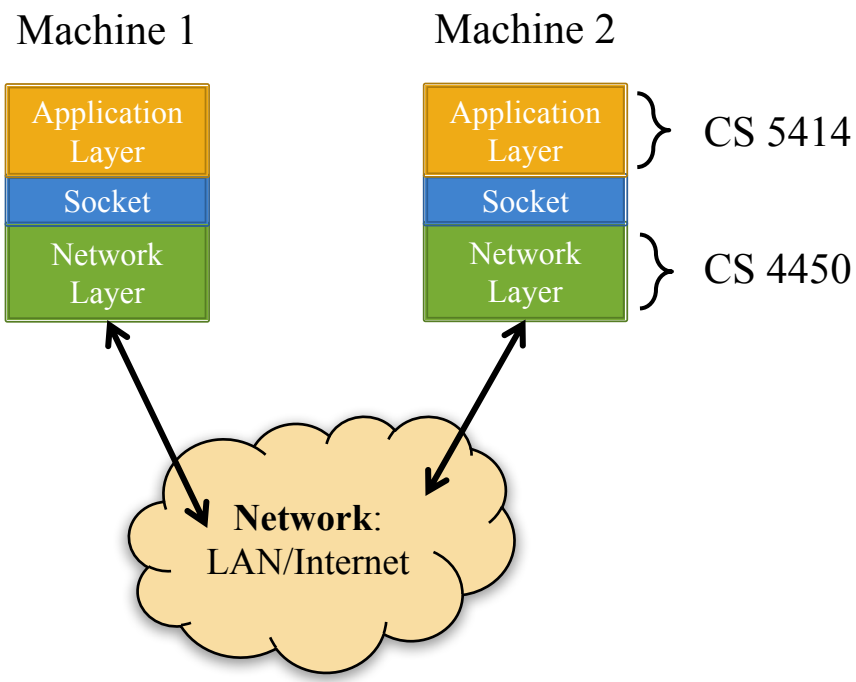


# Architecture: Peer-to-Peer



# Basic Networking Concerns

- Networking topology
  - Client-server
  - Peer-to-peer
- Computing model
  - Distributed objects
  - Message passing
- Communication protocol
  - TCP vs. UDP
  - UDP vs. Reliable UDP




**Not Today's Subject!**

# Game Networking Issues

## Consistency

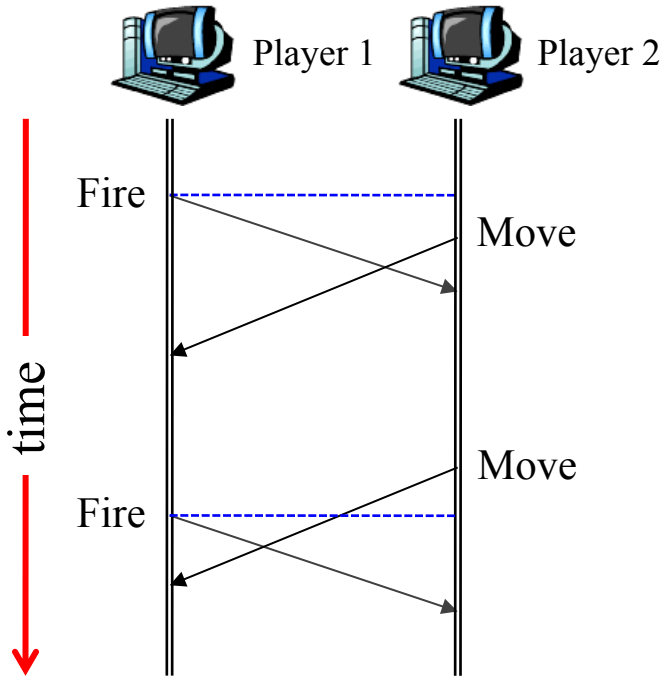
- Do our games agree?
  - Where do I see objects?
  - Where do you see them?
  - Who is **authoritative**?
- How to force agreement?
  - Do I wait for everyone?
  - Do I guess and fix errors?

## Security

- What cheats are possible?
  - View hidden data
  - Enter invalid states
  - Improve player skill
- How do we cheat proof?
  - Technical solutions?
  - Community policing?

# Consistency

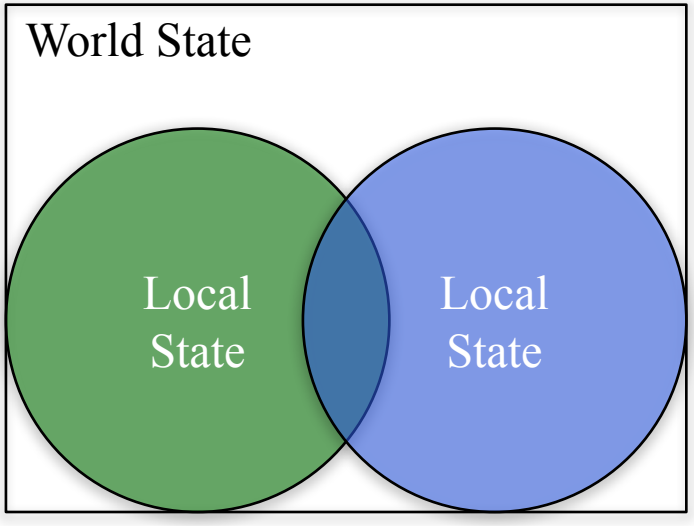
- *Latency* is root of all evil
  - **Local** actions are instant
  - **Network** actions are slow
- **Example**: targeting
  - Want "geometric fidelity"
  - Fire a weapon along ray
  - Hits first object on ray
  - But movement is fast!




How to tell these cases apart?

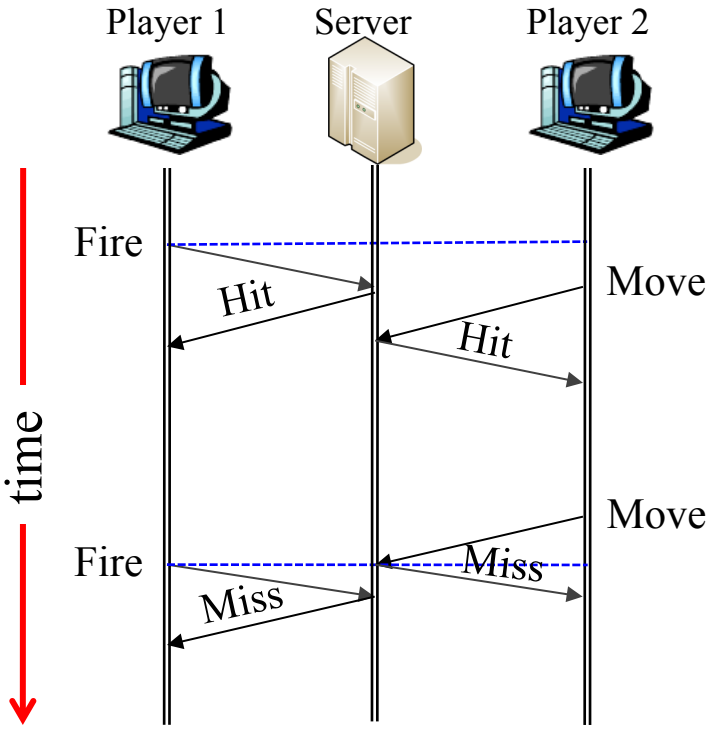
# World State vs. Local State

- **State**: all objects in game
  - **Local State**: on a machine
  - **World State**: "true" state
- *Where* is the world state?
  - Not on any one machine
  - Union of local states?
- States may be *inconsistent*
  - Local disagrees with world
  - Is this really a problem?
  - What can we do about it?



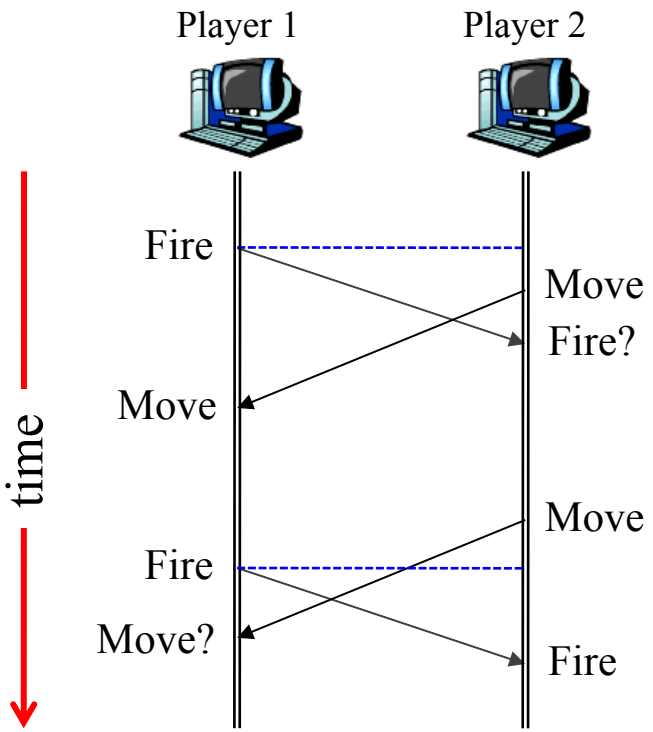
# Server Side Consistency

- Server has the world state
  - Actions update world state
  - Server updates local states
- **Issue**: ordering actions
  - Order by receipt?
    - Lower latencies benefit
  - Time action is sent?
    - Need synchronized clock
    - Major open problem in CS
- When is okay to draw?



# Peer-to-Peer Consistency

- Similar issues as server
  - When to render a move?
    - Do I wait for opponents?
    - How long do I wait?
  - What to render before that?
- No authoritative world state
  - Relatively easy to cheat
    - Word state = union of local
    - Alter your local state!
  - Only for small/short games



# Pessimistic Consistency

- Everyone sees same world
  - Ensure local = world state
  - *Synchronization* algorithms
- *Age of Empires/Mythology*
  - Each player simulates world
  - Players send only moves
- Uses *bucket synchronization*
  - Monitors round trip time
  - Dropped packets resent
  - Adjusts future bucket sizes

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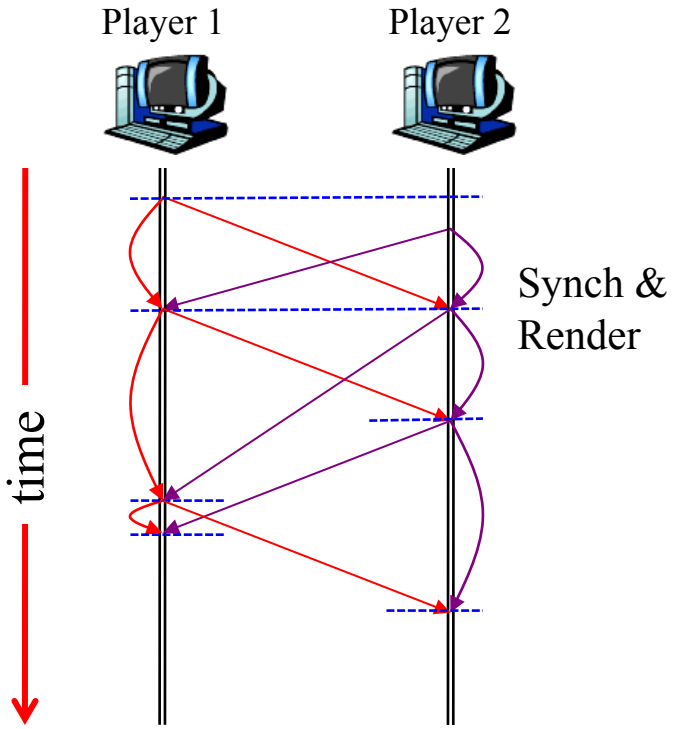
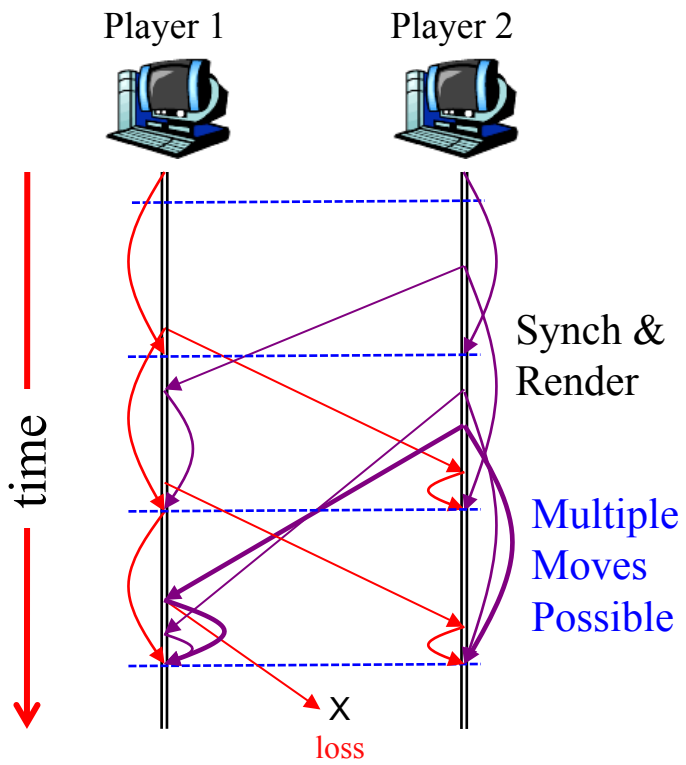
# Lock-Step Synchronization

- **Algorithm**: play by "turns"
  - Players send turn actions
  - Even if no action was taken
  - Wait for response to render
- **Problems**
  - *Long* Internet latency
  - Variable latencies (jitter)
  - Speed set by slowest player
  - What if moves are lost?
- More common in LAN days



# Bucket Synchronization

- **Algorithm**: turns w/ timeout
  - Often timeout after 200 ms
  - But can be adapted to RTT (round trip time)
  - All moves are buffered
  - Executed at end of *next* turn
- **Problems**
  - Variable latencies (> a turn)
  - Speed set by slowest player
  - What if moves are lost?

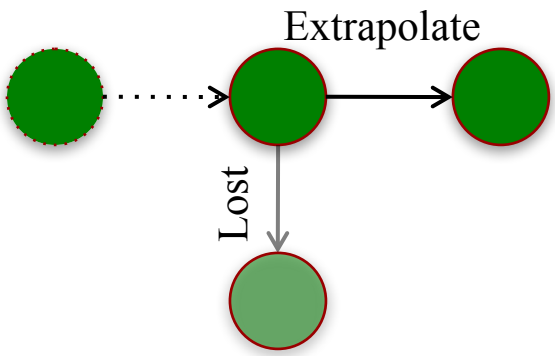


# Optimistic Consistency

- Best guess + roll back
  - Do not wait for others
  - Fix mistakes if needed
  - Only send *major* events
- **Half-Life**: client-server
  - Client acts immediately
    - Sends moves to the server
    - Guesses other' moves
  - Server computes *true world*
    - Sends its version to clients
  - Client reconciles *differences*

# Dead Reckoning

- Need some way to handle slow players
  - Want to "predict" what their actions will be
  - Use predictions if action lost or late
- Dead reckoning: movement extrapolation
  - Players send velocity, acceleration with each move
  - Assume this is unchanged if no action received

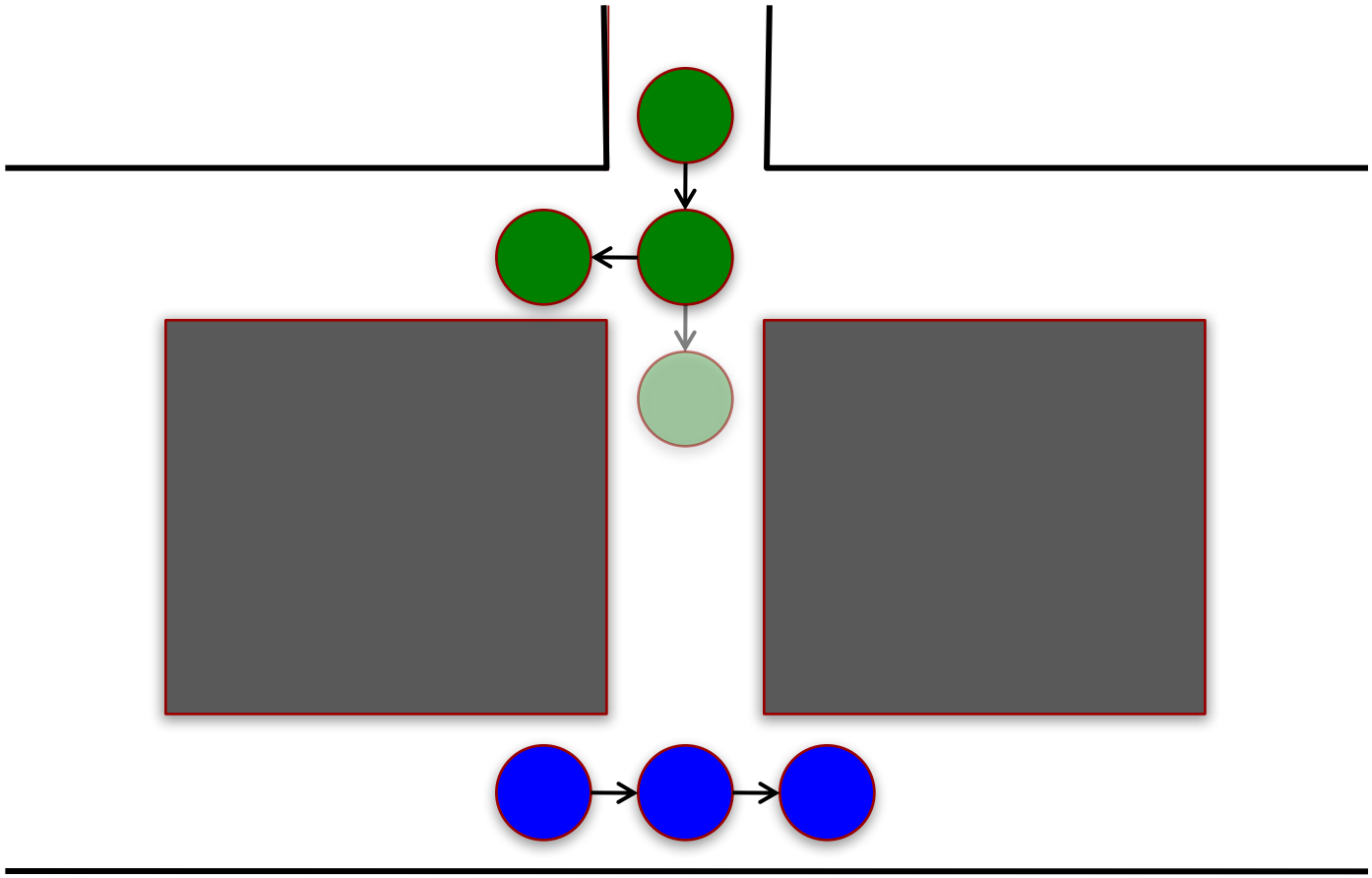


# Roll-Back

- Dead-reckoning introduces inconsistency
  - You see your intended move
  - Other players see your extrapolated moves
- Make one computer *authoritative*
  - Server in client-server architecture
  - More complicated for peer-to-peer

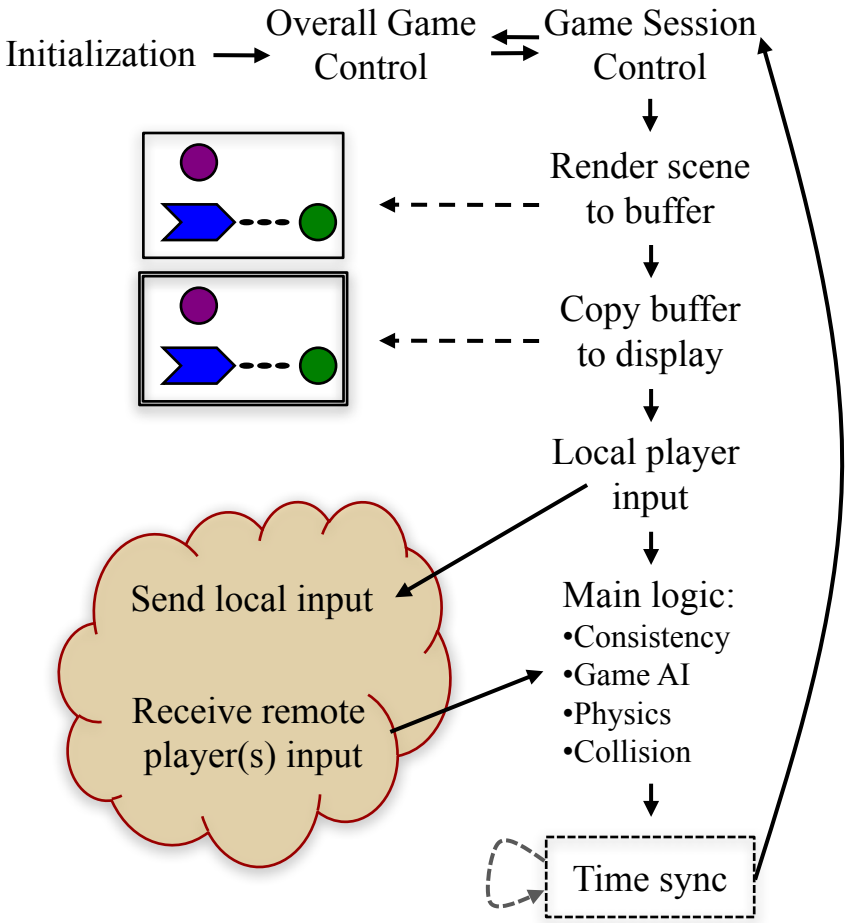
- **Roll-back**: Replace guess with authority
  - Players may experience "warping"
  - Can improve with smoothing algorithms

# Shooting Around Corners



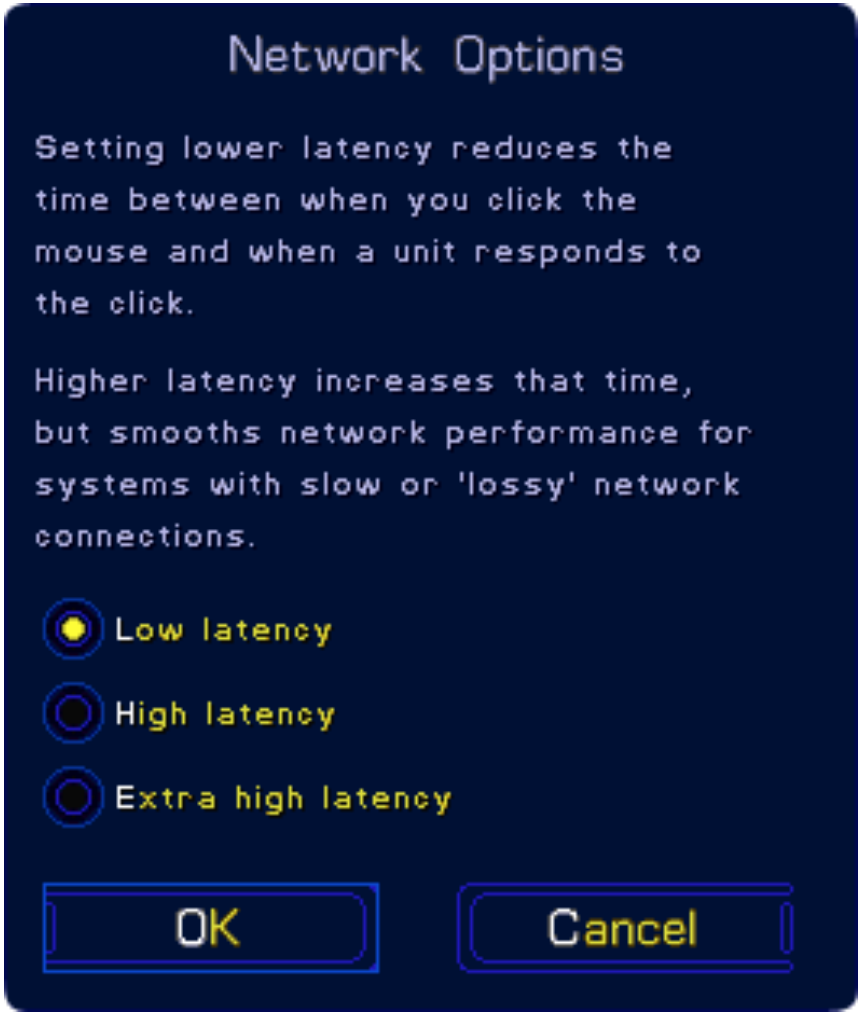
# Consistency: Correctness

- Make multiplayer from start
  - Adding later is very difficult
  - Single player is special case
  - AI/network interchangeable
- Eliminate **non-determinism**
  - Random rolls are a problem
  - Generate from the server
  - Or use same random seed
- **Input** must be synchronized
  - Or else will get state "drift"



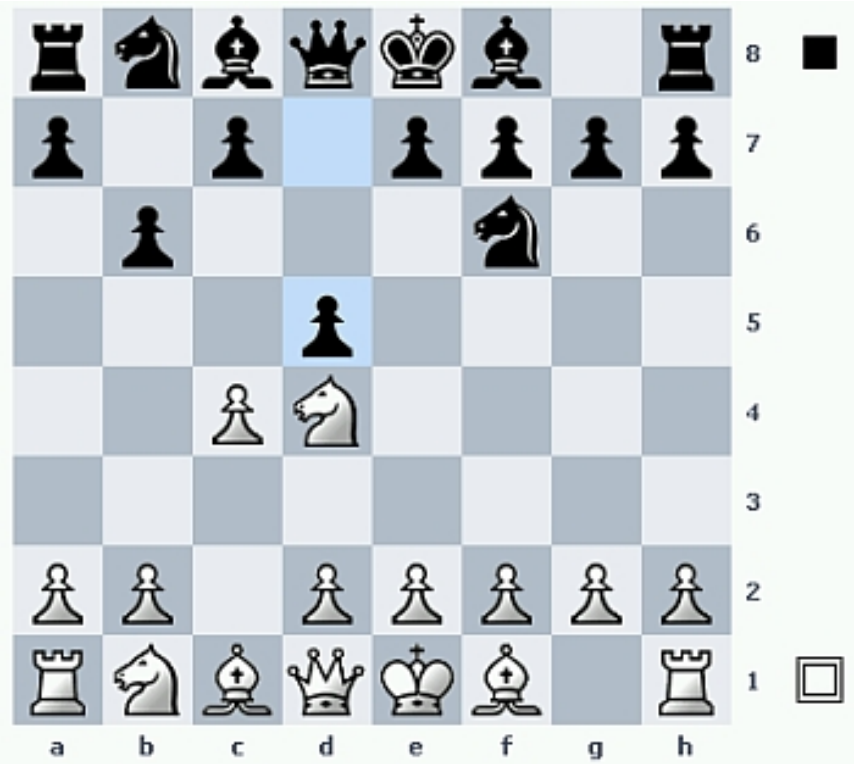
# Consistency: Smoothness

- For smoother playback
  - Decouple turn & frame rate
  - Always draw local moves
  - Design for latency and loss
- Latency masking
  - Players wait for elevator
  - Teleportation takes time
  - Many hits needed per kill
  - Bullets have flying time
  - Inertia limits movement



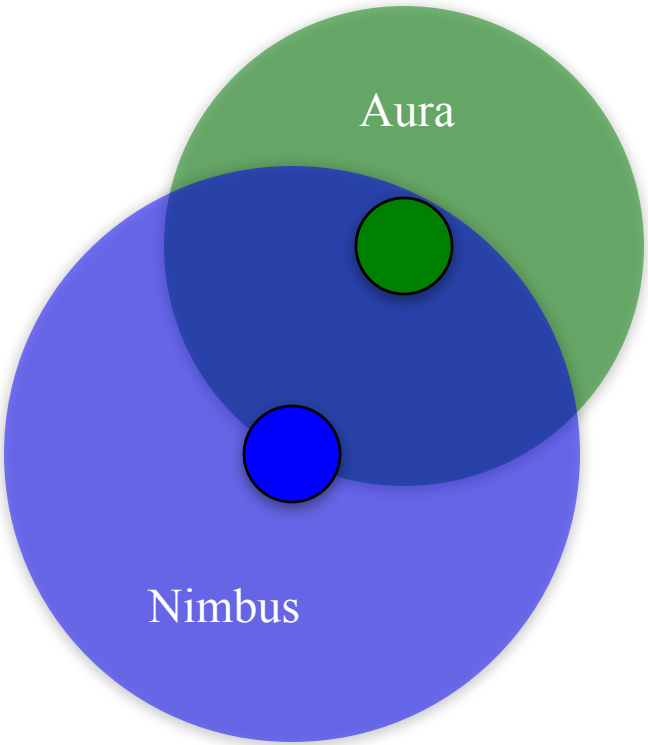
# Consistency: Design Solutions

- Limit possible conflicts
  - Authoritative for own state
  - Minimize amount to guess
  - Make roll-back rare/simpler
- **Game design** solutions
  - Software solutions are hard
  - So make game state *simpler*
- **Examples**
  - Area of interest management
  - Coarse state fidelity



# Area of Interest Management

- Aura and Nimbus
  - **Aura**: visibility radius
  - **Nimbus**: detect radius
- Given by "technology"
  - **Aura**: cloaked ship
  - **Nimbus**: sensor
- Consistency check if
  - *B* is within *A*'s nimbus
  - *A* is within *B*'s aura



# Course State Fidelity

- State need not be exact
  - Often just need an estimate
  - Send estimate over network
  - Handle details locally
- **Example**: tiled games
  - Just need grid location
  - Do not send movement
  - Animate motion locally
- Animation vs. gameplay
  - Many frames = one action
  - Keep interactions simple

# World of Warcraft

- Coarse spatial fidelity
  - Not sure of exact position
  - Exact targeting impossible
- How to deal with this?
  - Open, airy buildings
    - Few corners to hide with
  - Attacks are automatic
    - Misses are a random roll
  - If you see it, you can hit it
- **Is this a challenge?**

# World of Warcraft

- Make challenge strategic!
  - NPCs have well-defined AI
  - Affects order/type of attacks
  - Players must learn exploits
  - "Chess-like combat"
- Aggro Management
  - Picks who NPCs attack
  - Draw aggro to shield others
  - Replaces *spatial cover*
- Allows 1 second latencies!

# Summary

- Consistency is primary issue in network games
  - **Inconsistency**: local state deviates from word state
  - Caused by latency; takes time for action to be sent
  - Requires complex solutions since must draw now!
- Two primary consistency techniques in use
  - **Pessimistic**: All clients must agree with world state
  - **Optimistic**: Can deviate from world state; roll back
- Next time: **Security**