the gamedesigninitiative at cornell university

Networking

CS 3152: 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?

CS 3152: Game Networking Issues

Consistency

- Do our games agree?
  - Where do I see objects?
  - Where do [illegible]
- How to force agreement?
  - Do I wait for everyone?
  - Do I guess and fix errors?

Today's Lecture

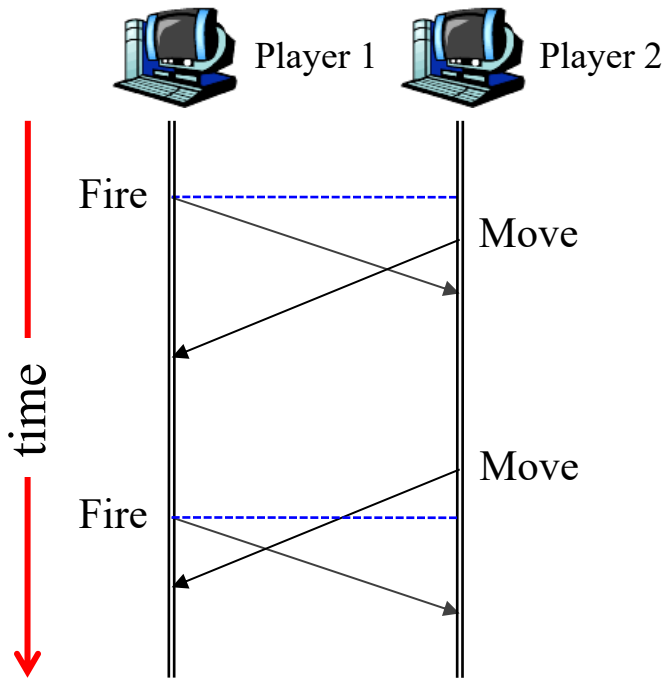
Security

- What cheats are possible?
  - View hidden data
  - Enter [illegible]
- How do we cheat proof?
  - Technical solutions?
  - Community policing?

Not going to cover

The Issue of Consistency

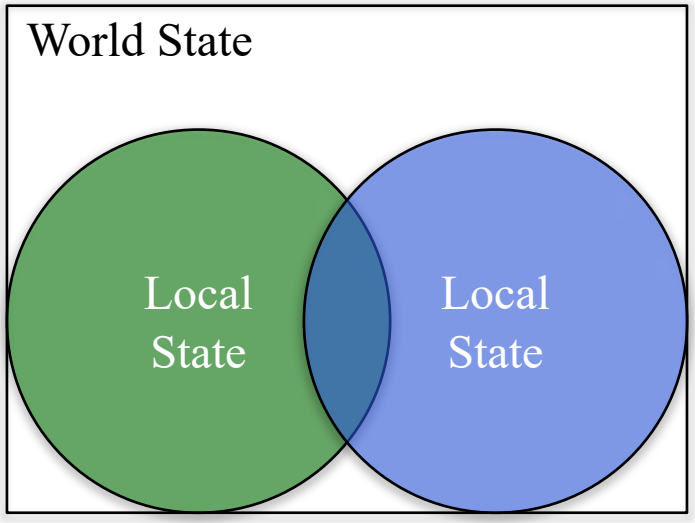
- *Latency* is root of all evil
  - **Local** actions are instant
  - **Network** actions are slow
- **Example**: targeting
  - Want "geometric fidelity"
  - Fire a weapon along ray
  - Hits first object on ray
  - But movement is fast!



How to tell these cases apart?

World State vs. Local State

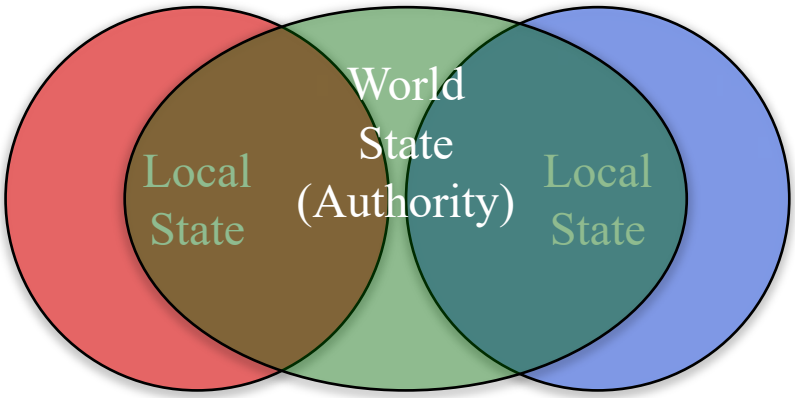
- **State**: all objects in game
  - **Local State**: on a machine
  - **World State**: "true" state
- *Where* is the world state?
  - On a single machine?
  - Union of local states?
- States may be *inconsistent*
  - Local disagrees with world
  - Is this really a problem?
  - What can we do about it?



The Question of Authority

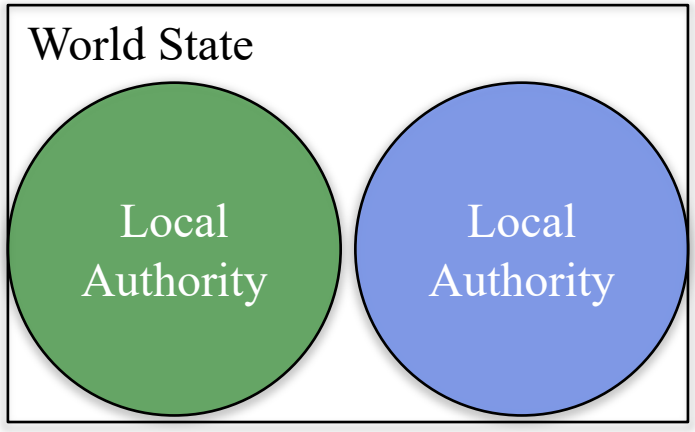
Centralized Authority

- One computer is authority
  - Stores the full world state
  - Local states must match it
- Often call this the “server”

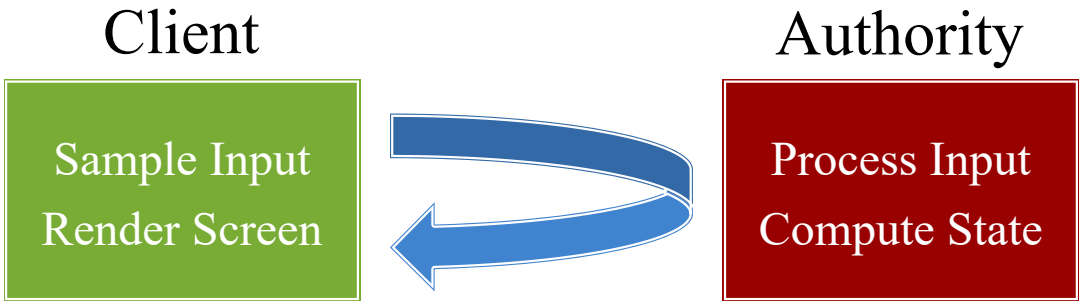


Distributed Authority

- Authority is divided up
  - Each object has an owner
  - Must match if not owner
- Classically call this “P2P”

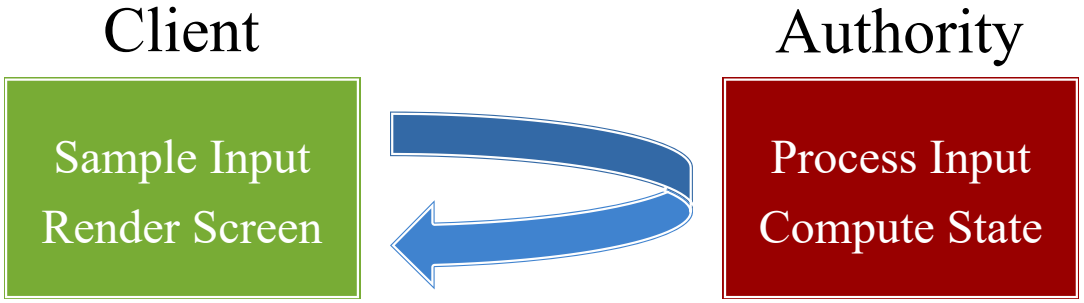


Authority and Latency



- Lack of authority enforces a delay
  - Only draw what authority tells you
  - Requires round trip from your input
  - Round-trip time (RTT) can be > 200 ms
- This makes the game less responsive
  - Need some way to compensate for this

Authority and Latency



- Lack of authority enforces a delay
  - Only draw what authority tells you
  - Requir
  - Need to understand basics before solving this
- This makes the game less responsive
  - Need some way to compensate for this

Networking Breaks into Two Phases

Matchmaking

- Service to find other players
  - Groups players in a session
  - But does not run session
- Why make your own?
  - Control user accounts
  - Implement skill ladders
- 3rd party services common
  - Apple GameCenter
  - GooglePlay API
  - Unity's server classes

Game Session

- Service to run the core game
  - Synchronizes player state
  - Supports minor adds/drops
- Why make your own?
  - Must tailor to your game
  - You often have no choice
- Limited 3rd party services
  - Often just a networking API
  - For limited class of games
  - **Examples**: Unity, Unreal

Networking Breaks into Two Phases

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Simplify if possible

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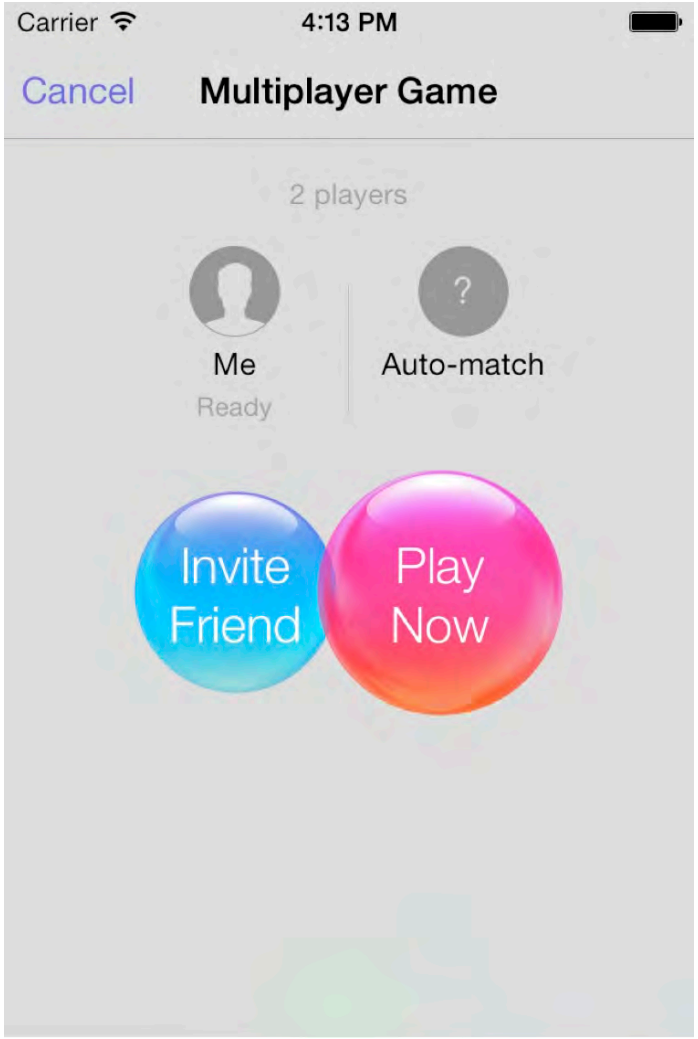
  - **Examples**: Unity, Unreal

Our main focus

Matchmaking: Apple/iOS

- Uses the **GameKit** library
  - Supports multiplayer games
  - Also leaderboards/achievements
  - Not a full game engine
- Very simple matchmaking
  - Specify the number of players
  - Invite anyone on friends list
  - Invite anyone in BlueTooth range
  - Or allow Apple to hook you up
- Can be simultaneous with session
  - Add more players if slots available



iOS Matchmaking Classes

Real Time

- You handle authority
  - Allows variety of strategies
  - Focus of rest of lecture
- `GKMatchmakerViewController`
  - Classic matchmaking UI
  - You add a listener/delegate
- `GKMatchmaker`
  - Controller with no UI
  - Allows a custom view

Turn Based

- Apple handles authority
  - Stores state on Apple server
- `GKTurnBasedMatchmaker-ViewController`
  - Classic matchmaking UI
  - You add a listener/delegate
- `GKTurnBasedMatch`
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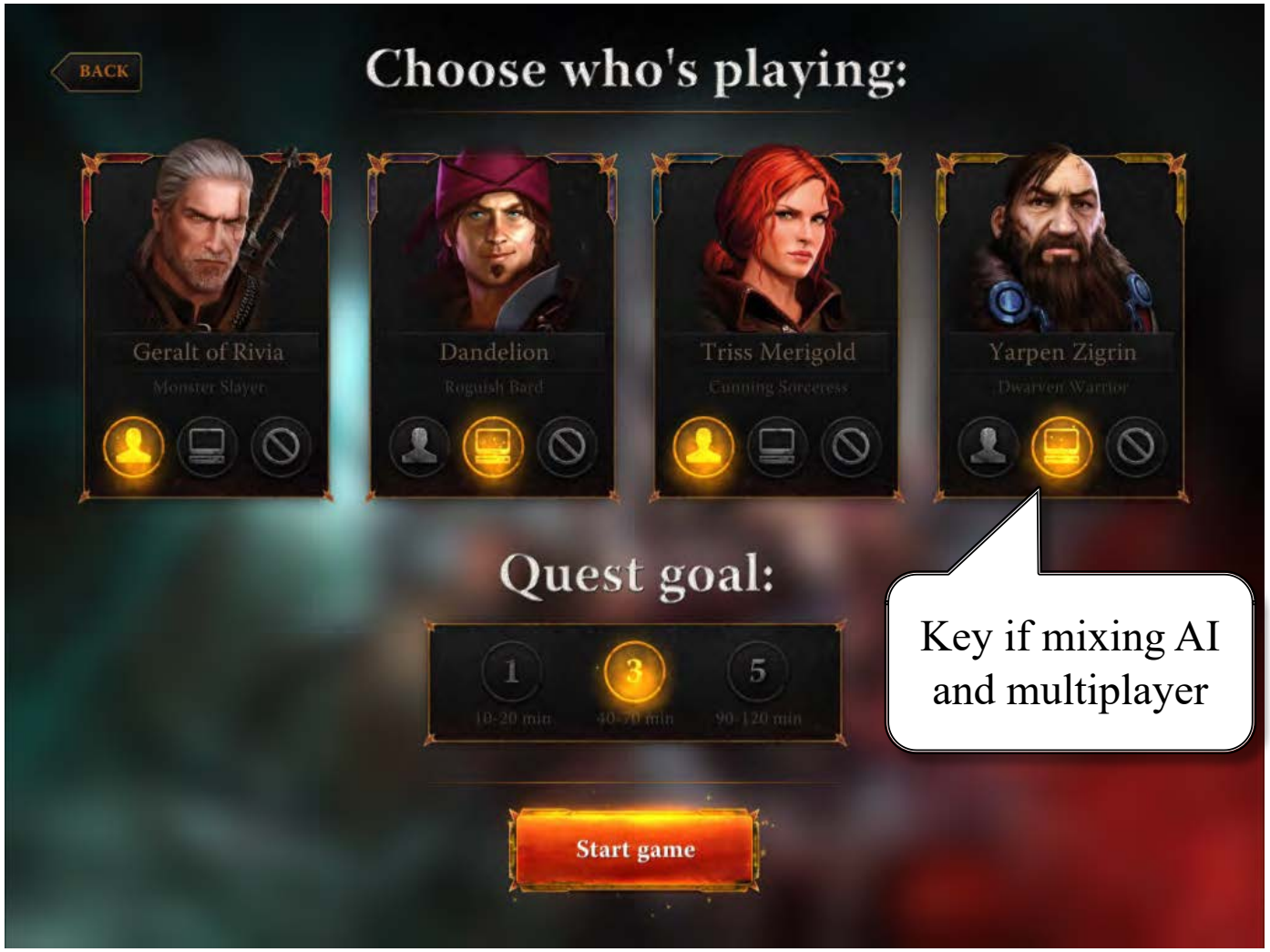
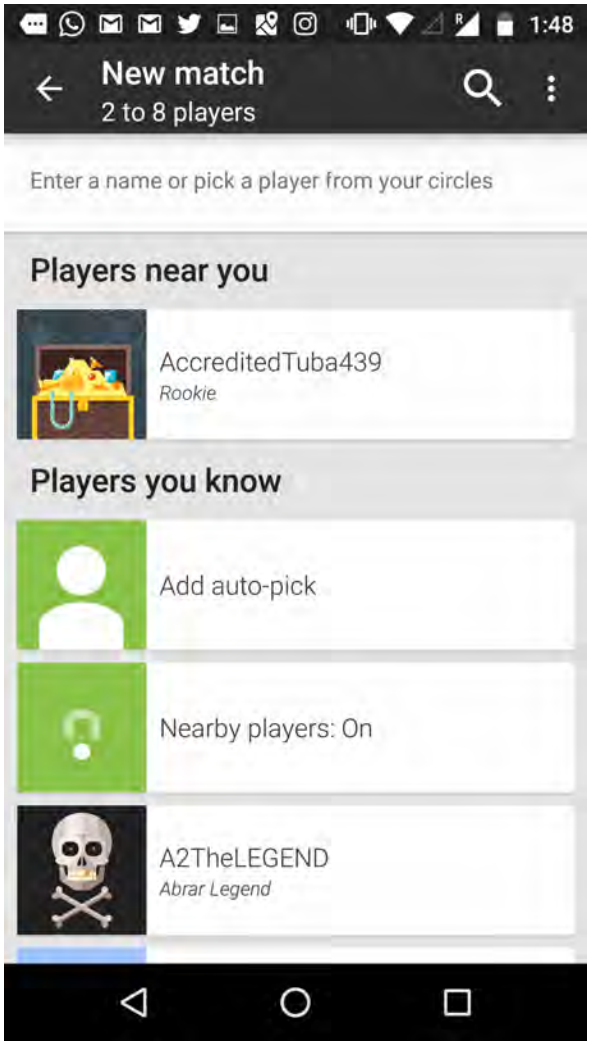
Will require you to use Objective-C++

Advantages of a Custom UI



Android **USED** To Have This Too

- Part of the Google Play API
  - Supported multiplayer games
  - Also leaderboards/achievements
  - Also some minor game analytics
- Worked exactly like `GameKit`
  - Choose real-time or turn-based
  - Use Google UI or a custom one
  - Only differed in terminology
- Had a native C++ API
  - No need for Java or JNI
  - Plug it straight in CUGL



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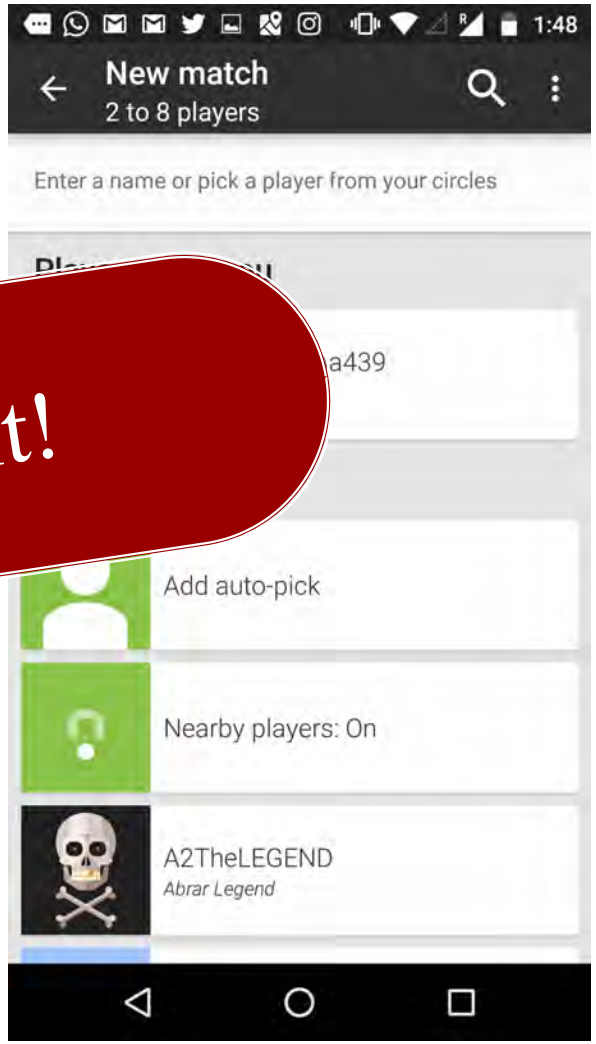
Google Killed It!



Modern Google Alternatives

Firebase

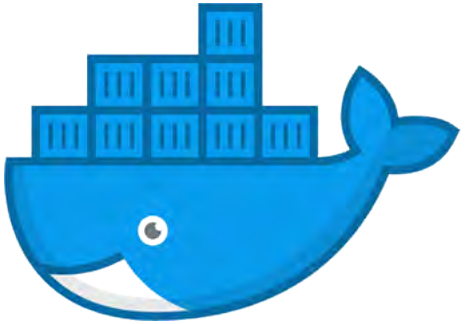
- Restful, realtime database
  - Simple syncing across apps
  - Makes consistency easy
- Can solve **both issues**
  - Groups players in matches
  - Sync state during session
- Used by *Family Style*
  - But server costs **expensive**!
  - Cheaper to just matchmake

Open Match

- Open source **matchmaker**
  - Runs on Kubernetes
  - Instance just for your game
- **No game session logic**
  - You still have to do this
  - But that is normally the case
- Made by Google/Unity
  - The future of Unity netcode
  - But is engine agnostic

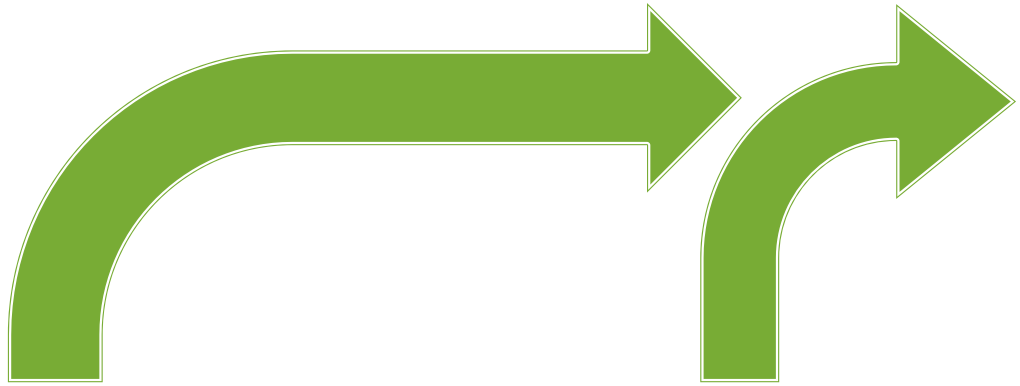
Custom Matchmaking

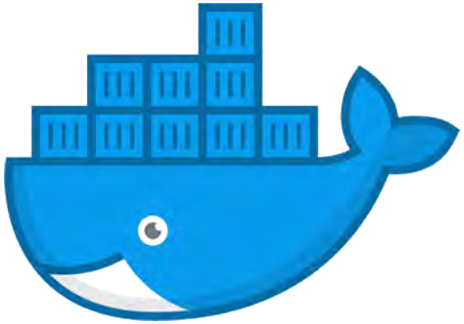
- You can make your own
  - Hard part is the server
  - Need a fixed IP address
  - IP is coded into the game
- But can leverage **cloud tech**
  - Write a Docker container
  - Or just use Firebase
- **Benefit**: cross-platform play
  - Must for iOS-Android play
  - Reason for Open Match



Custom Matchmaking

Ask for Game Session



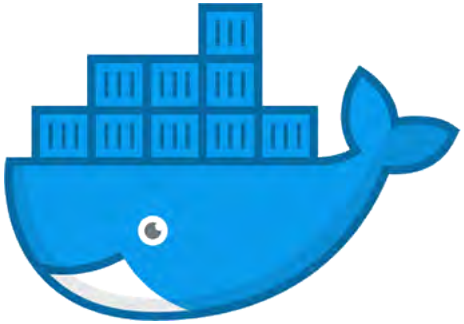


Client

Client

Custom Matchmaking

Respond with Group



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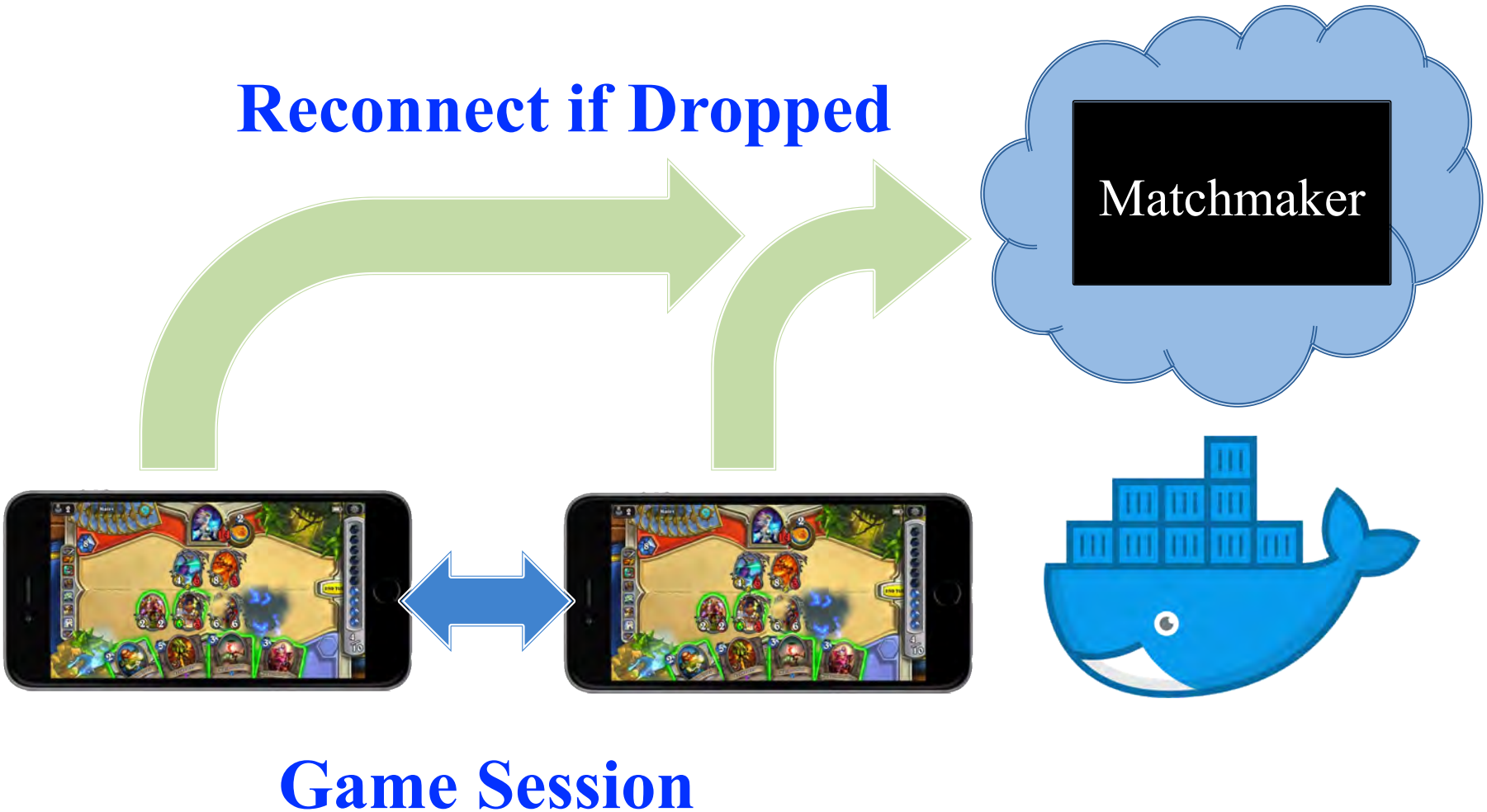
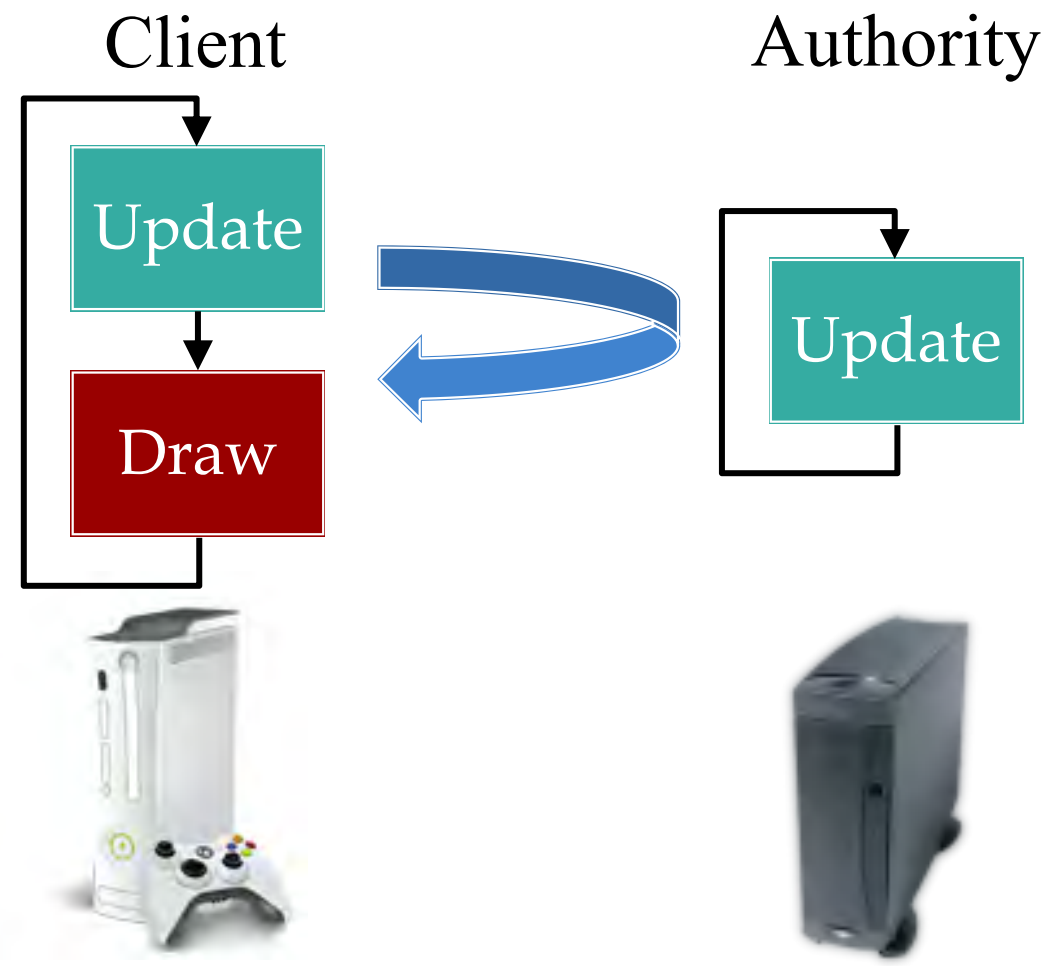


Matchmaking in *Family Style*

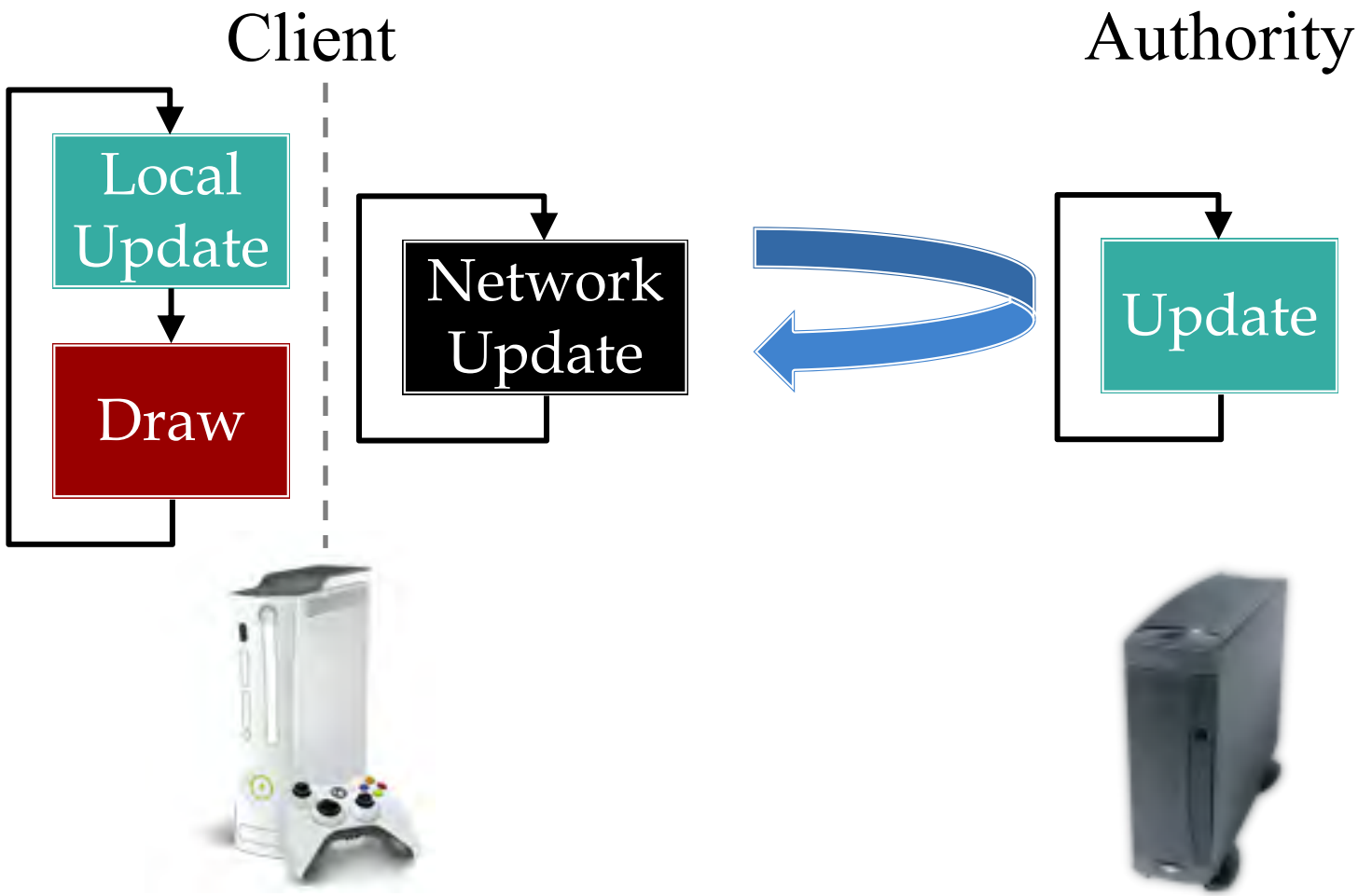
Why Not Just Direct IPs?

- **Idea:** Make one game "the server"
  - Player starts up server instance
  - Player writes down their IP address
  - Everyone else types in that IP address
- **Problem:** Network Address Translation
  - Most networks use NAT to attach many devices
  - This means IP addresses on NAT are not real
- Mathmaker provides **NAT punchthrough**!
  - Reason why you keep it open for reconnects

Game Session: Part of Core Loop



Decoupling the Network Loop



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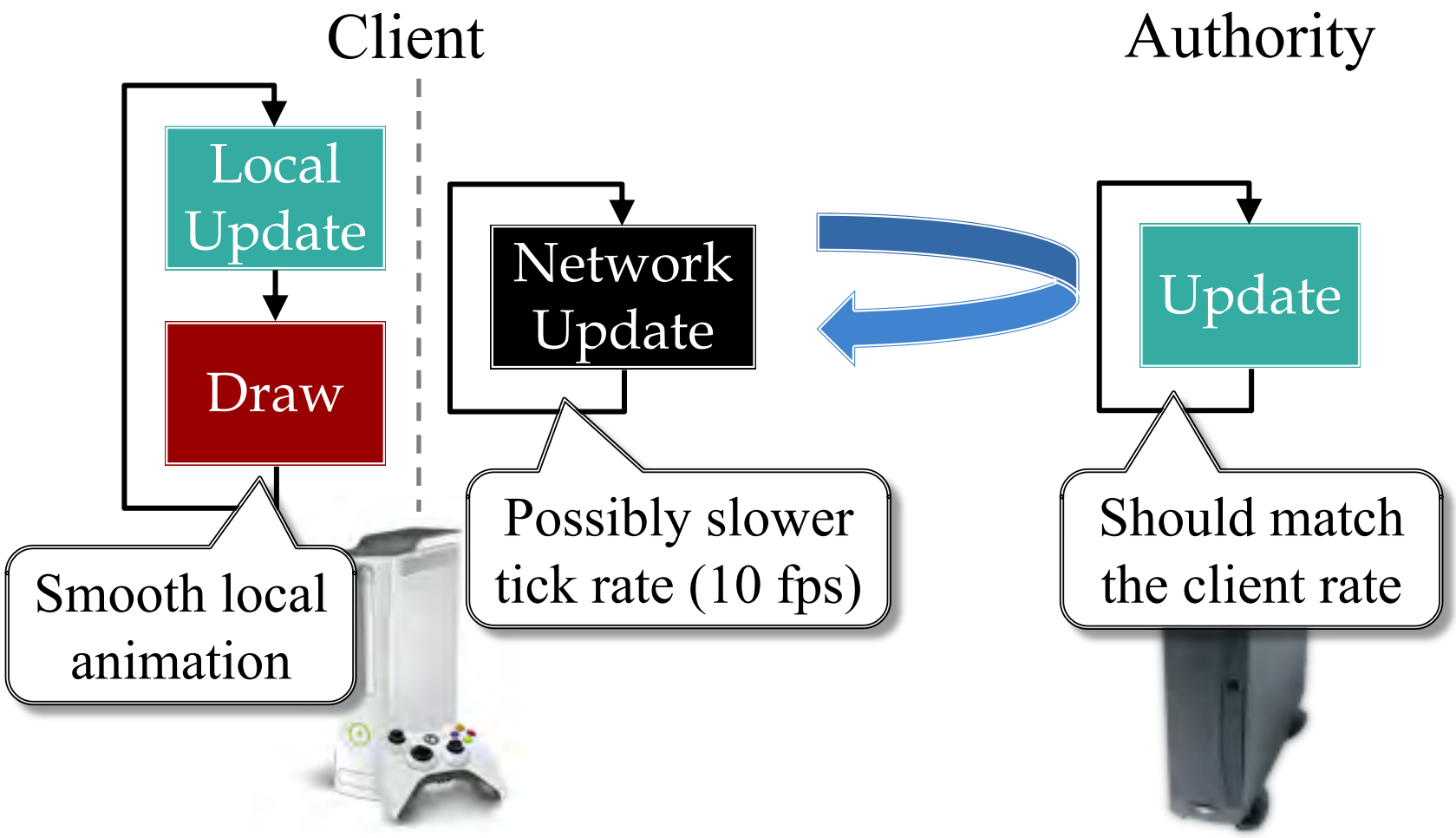
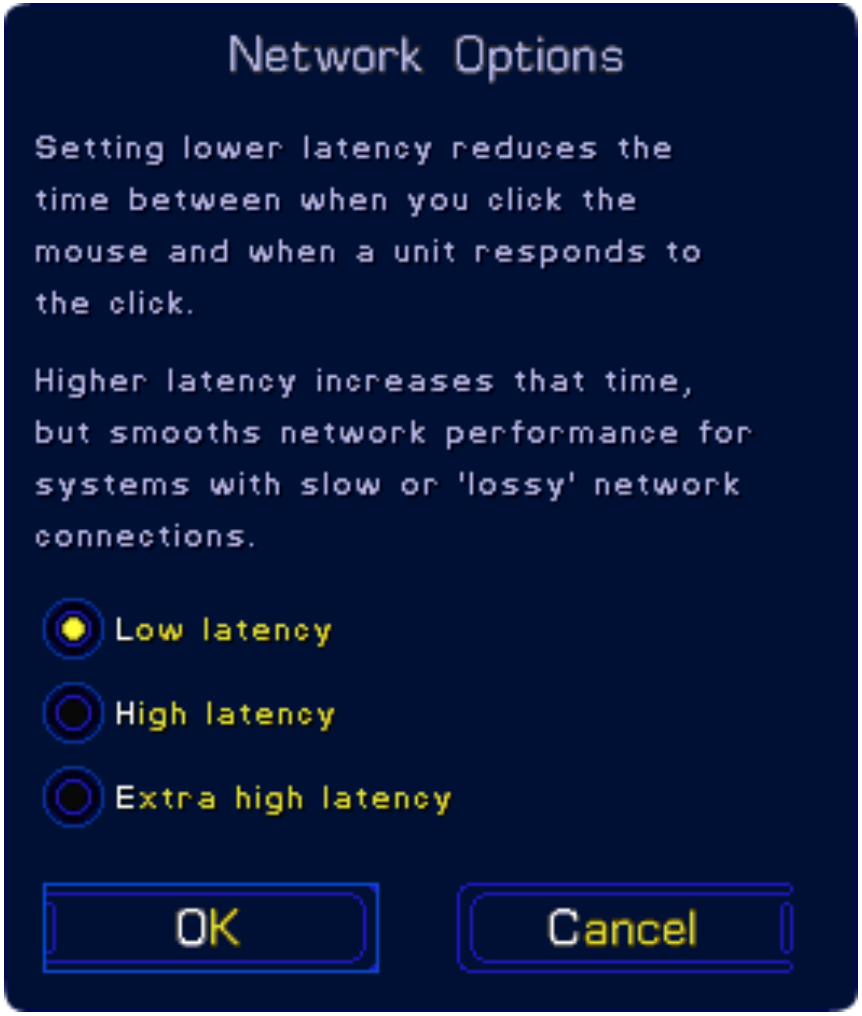


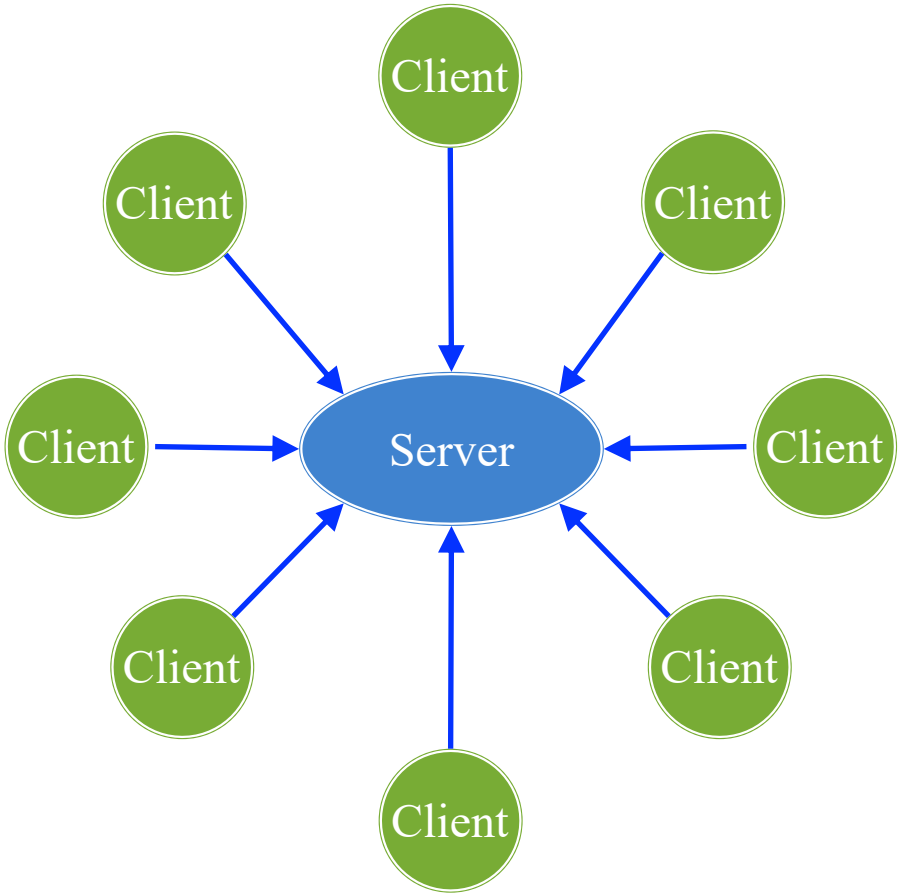
Decoupling Enables Latency Masking

- Animation is “buying time”
  - Looks fast and responsive
  - But no real change to state
  - Animation done at update
- **Examples:**
  - Players wait for elevator
  - Teleportation takes time
  - Many hits needed per kill
  - Bullets have flying time
  - Inertia limits movement



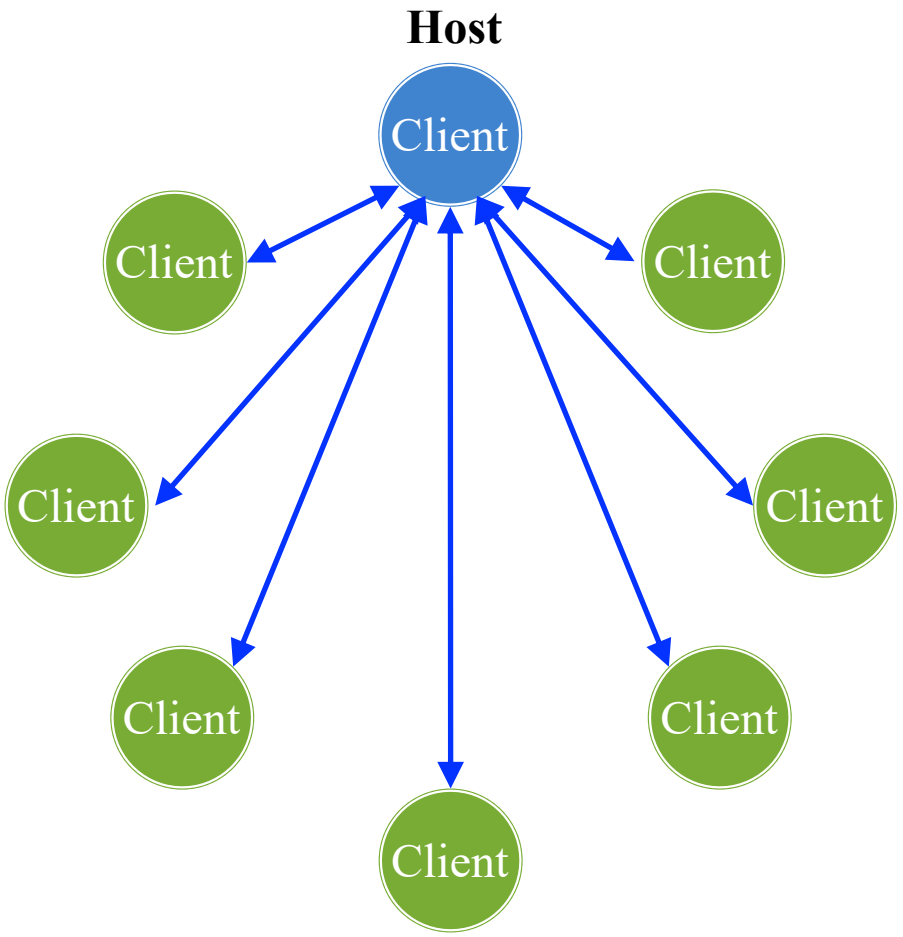
Game Session: Dedicated Server

- Server developer provides
  - Acts as central authority
  - May be several servers
  - May use cloud services
- **Pros:**
  - Could be real computer
  - More power/responsiveness
  - No player has advantage
- **Cons:**
  - Lag if players not nearby
  - Expensive to maintain



Game Session: AdHoc Server

- One client acts as host
  - Acts as central authority
  - Chosen by matchmaker
  - But may change in session
- **Pros:**
  - Cheap long-term solution
  - Can group clients spatially
- **Cons:**
  - Server is a mobile device
  - Host often has advantages
  - Must migrate if host is lost



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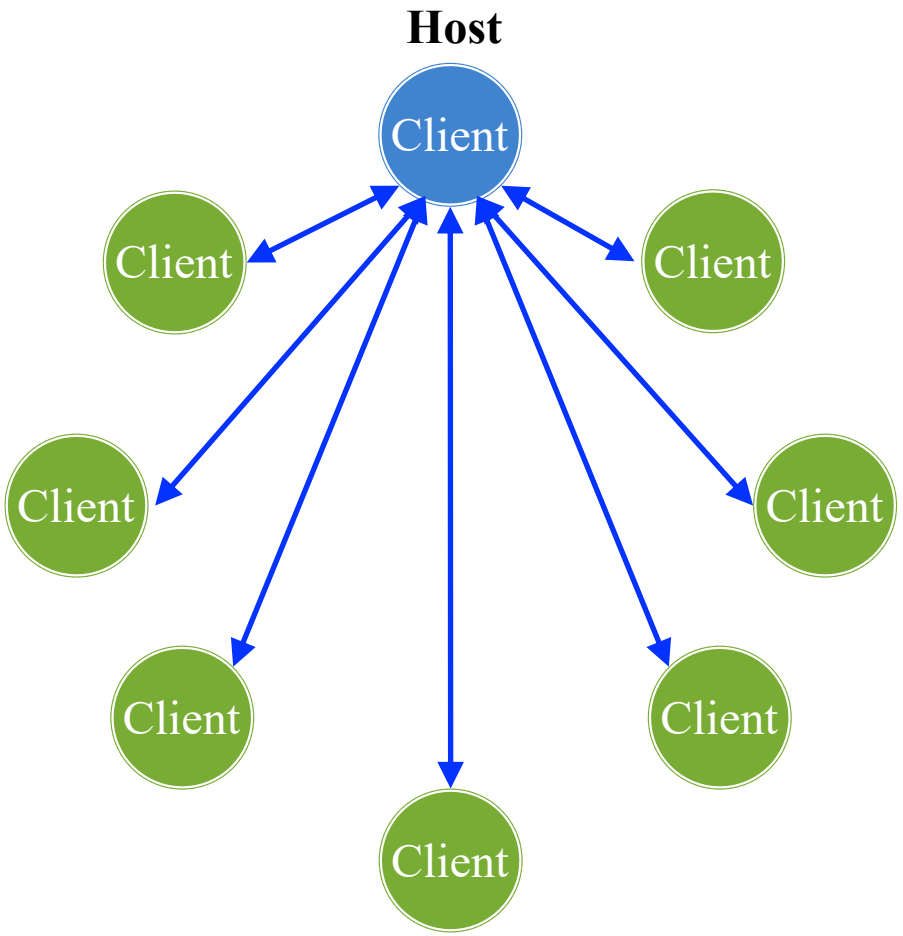
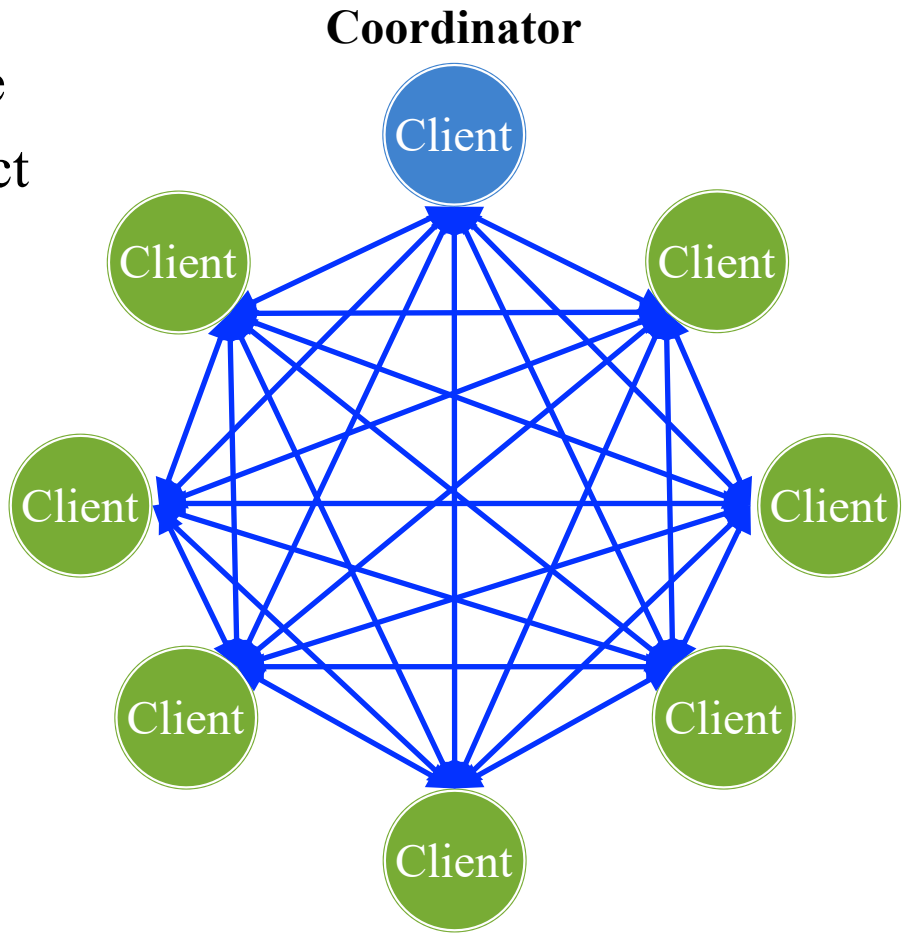
Predominant commercial architecture



Game Session: True P2P

- Authority is distributed
  - Each client owns part of state
  - Special algorithms for conflict
  - Coordinator for adds/drops
- **Pros:**
  - No lag on owned objects
  - Lag limited to “attacks”
  - Same advantages as adhoc
- **Cons:**
  - Incredibly hard to implement
  - High networking bandwidth



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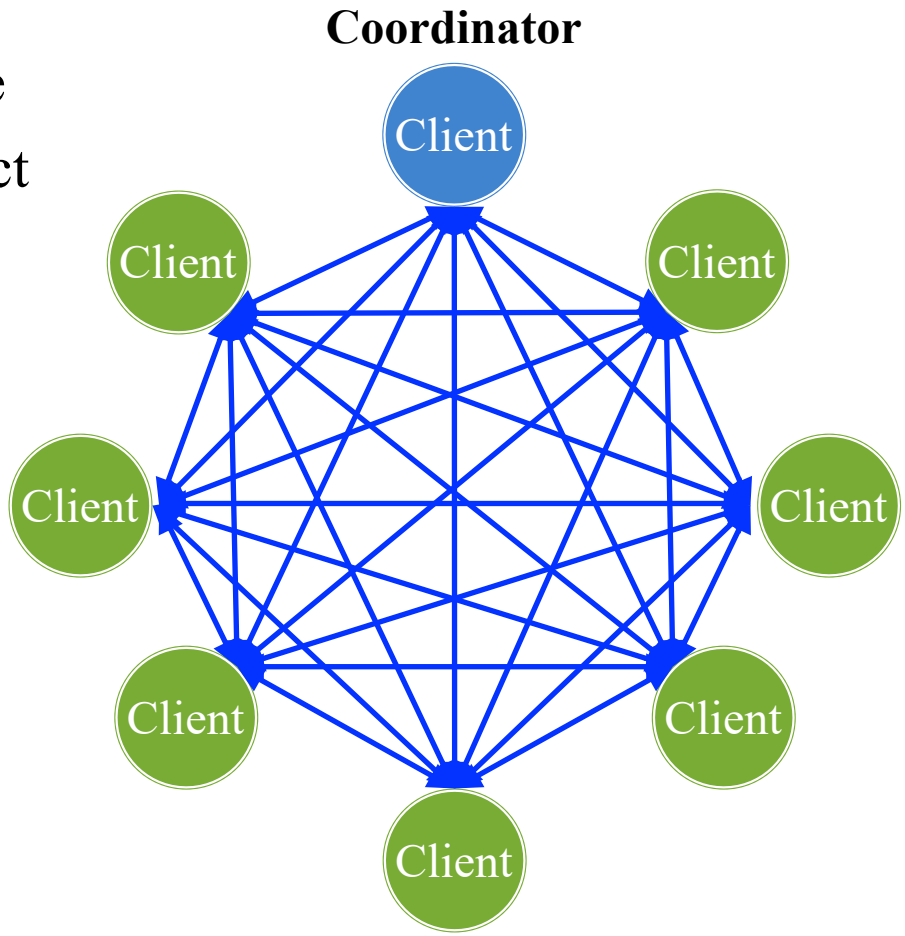
Almost no-one does this outside academia



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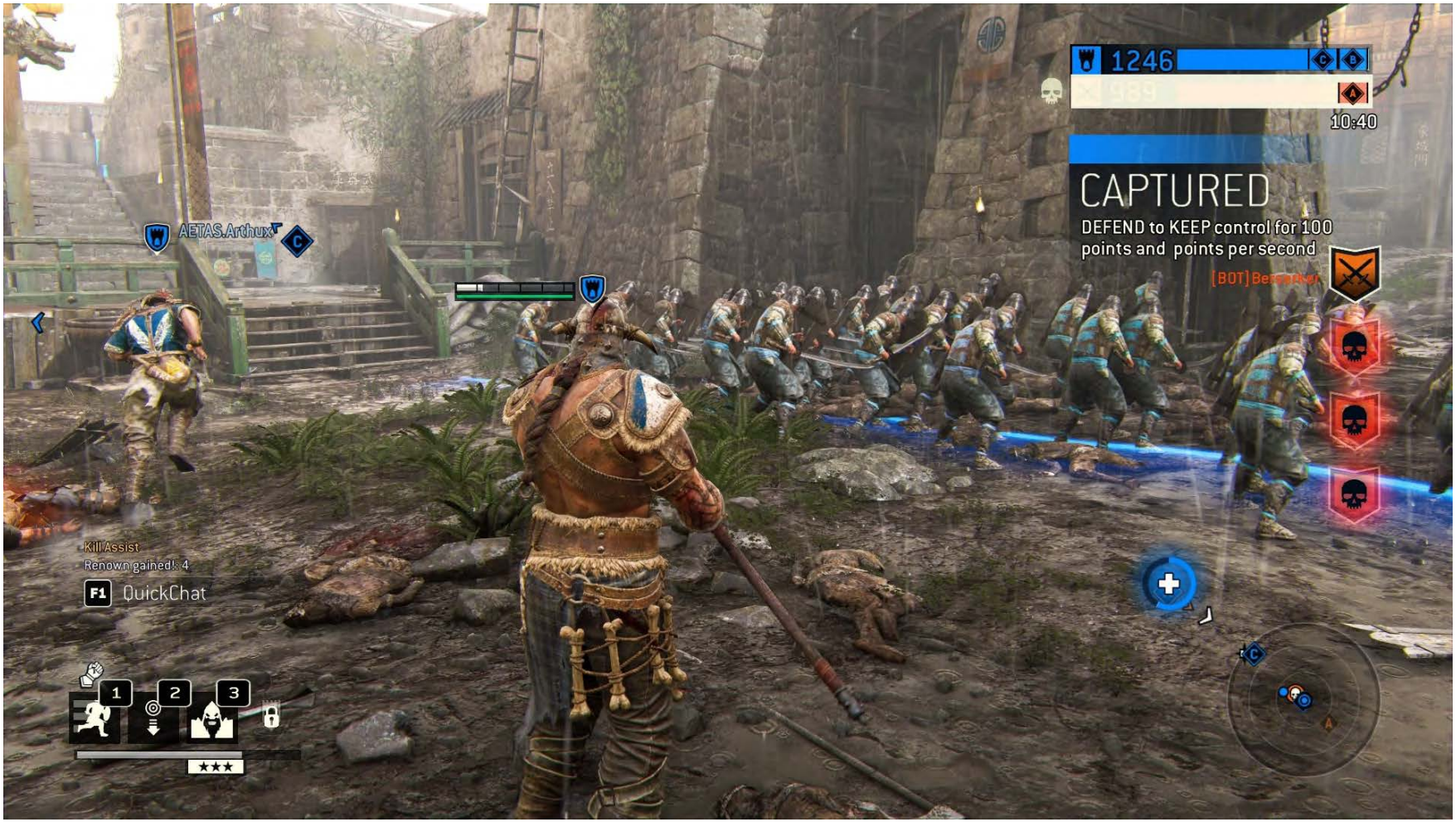
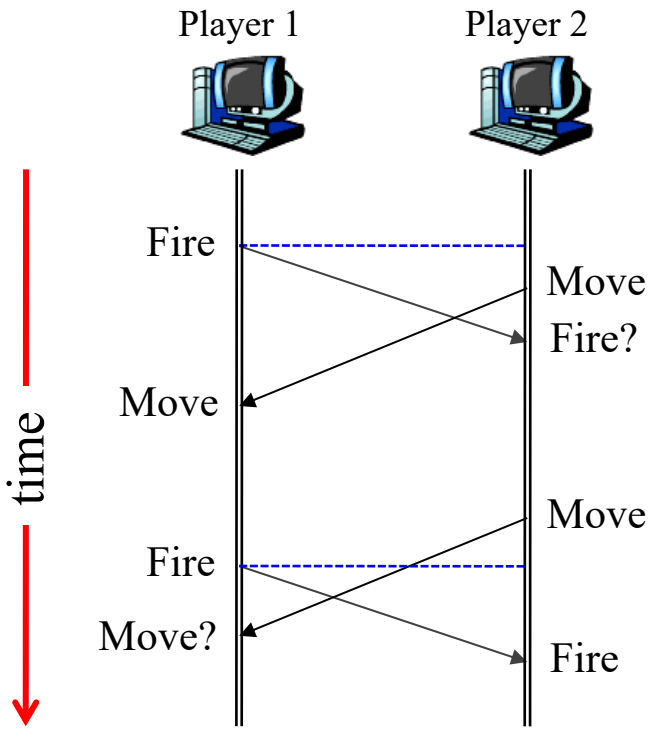


Game Session: True P2P

Synchronization Algorithms

- Clients must be **synchronized**
  - Ensure they have same state
  - … or differences do not mattter
- Synchronization != authority
  - Authority determines true state
  - Not *how* clients updated
  - Or *when* clients are updated
- Major concept in networking
  - Lots of complicated algorithms
  - Also a **patent mindfield**
  - Take distributed systems course



Synchronization Algorithms

Pessimistic

- Everyone sees same world
  - Ensure local = world state
  - Forces a drawing delay
- Best on fast networks
  - Local LAN play
  - Bluetooth proximity
- Or games with limited input
  - Real time strategy
  - Simulation games

Optimistic

- Allow some world drift
  - Best guess + roll back
  - Fix mistakes if needed
- Works on any network
  - Lag errors can be fixed
  - But fixes may be distracting
- Works great for shooters
  - Player controls only avatar
  - All else approximated

Synchronization Algorithms

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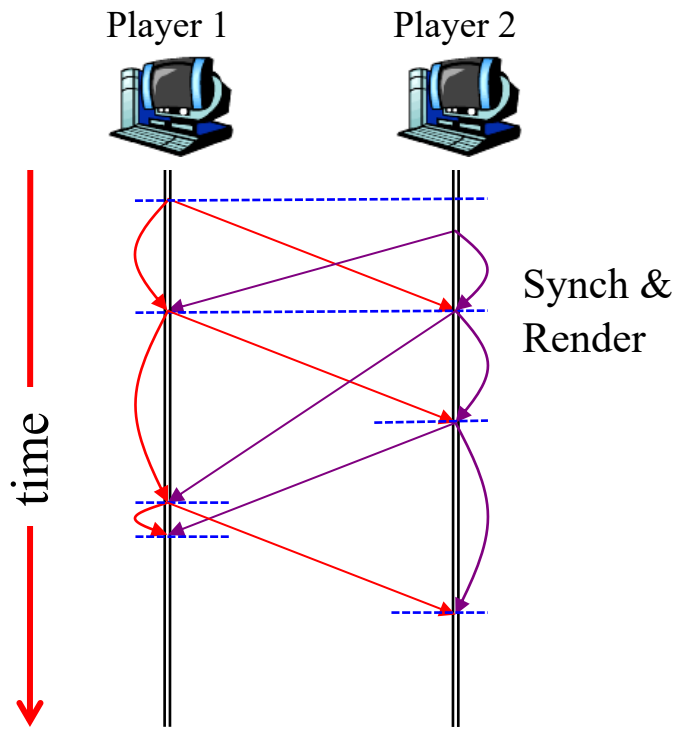
  - Can use approximated

Also great for distributed authority

Pessimistic: 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



Pessimistic: Bucket Synchronization

- **Algorithm**: turns w/ timeout
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  - All moves are buffered
  - Executed at end of *next* turn
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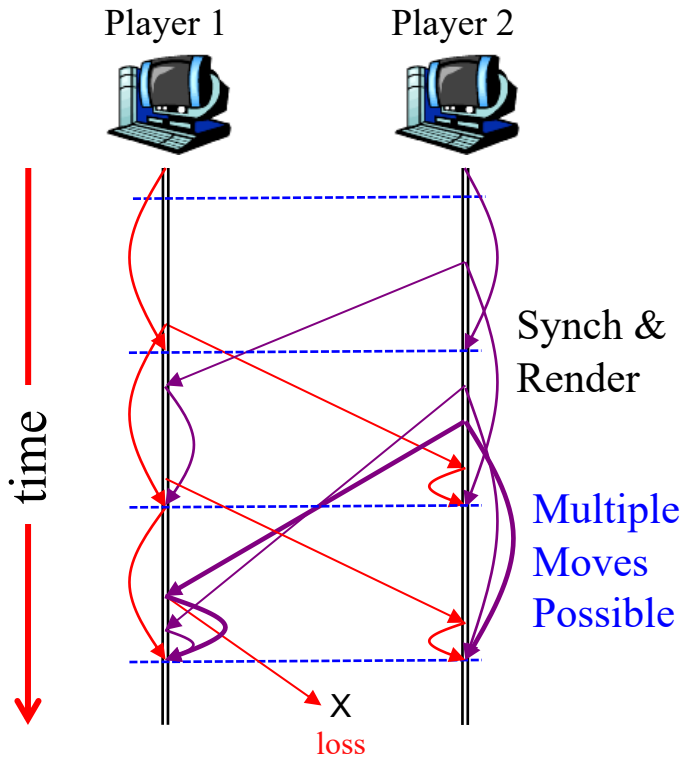
- Used in classic RTS games



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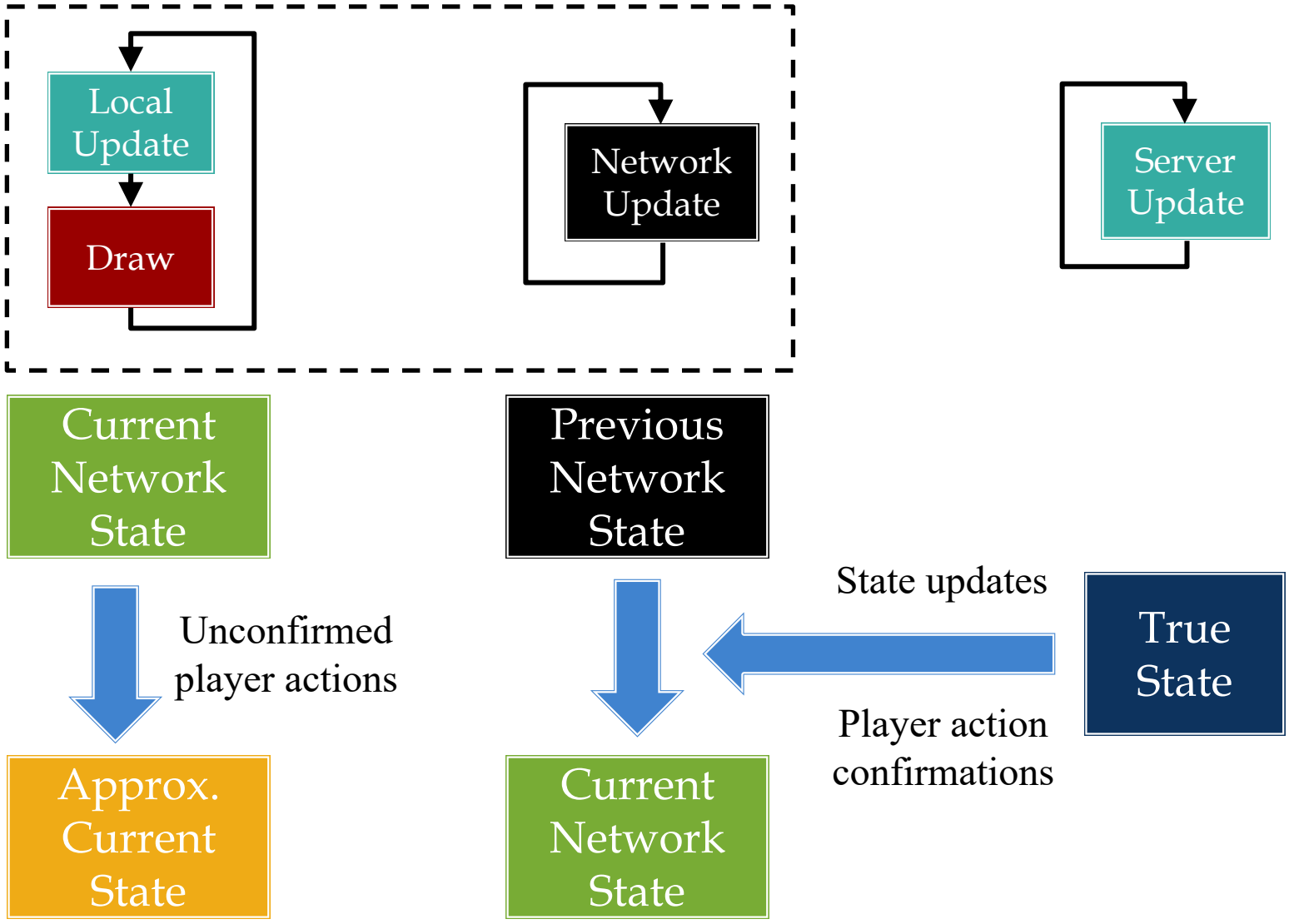
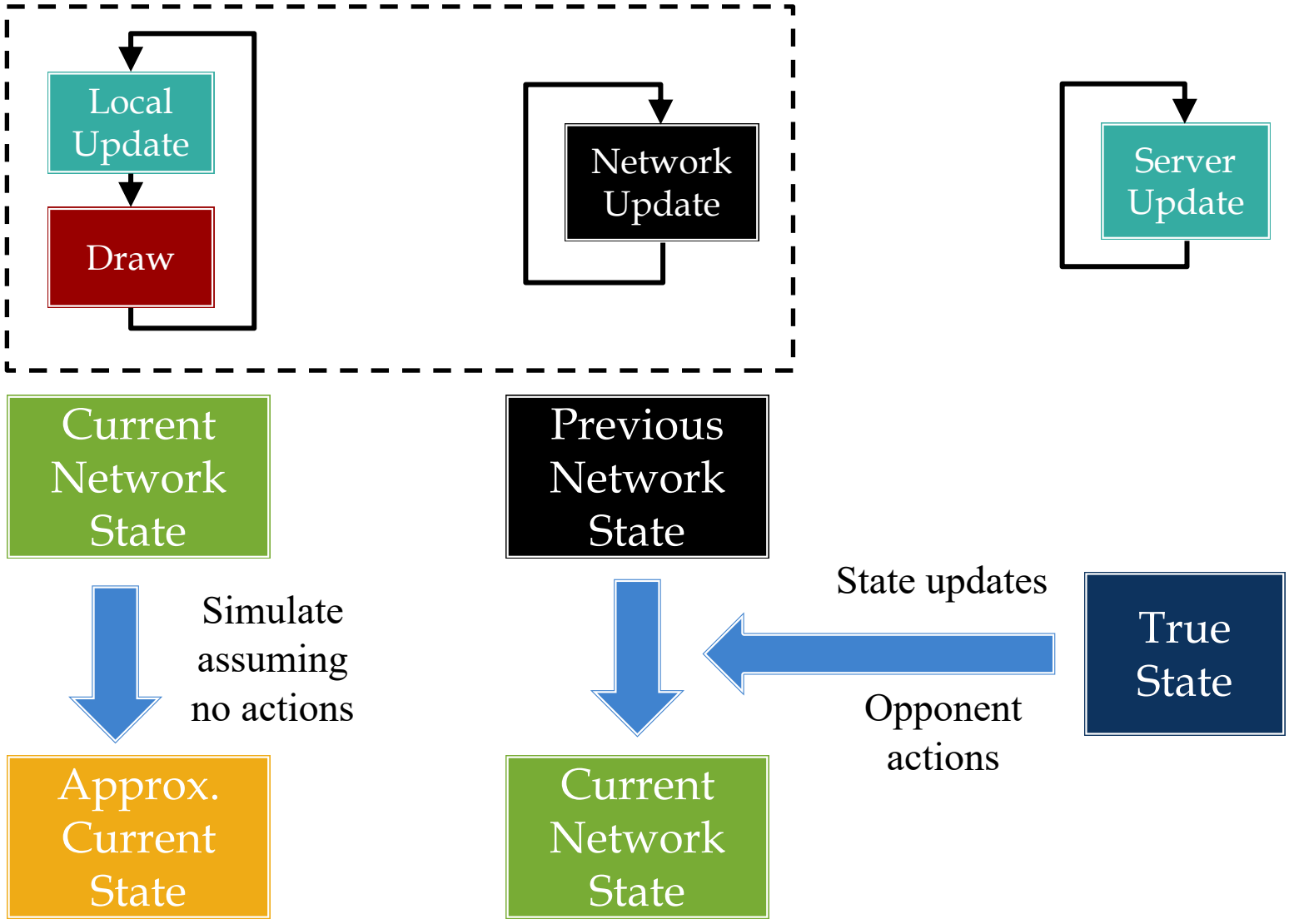
Optimistic: Personal State



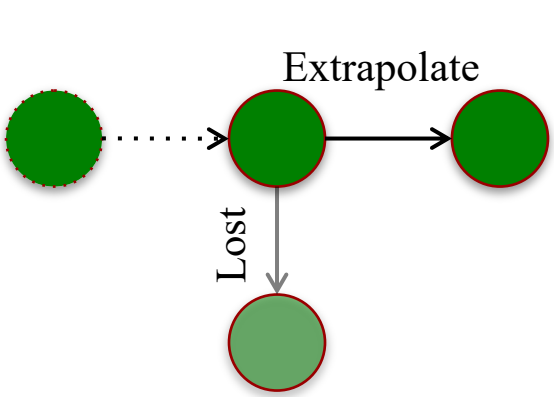
Optimistic: Opponent State



Advantages of Sending Actions

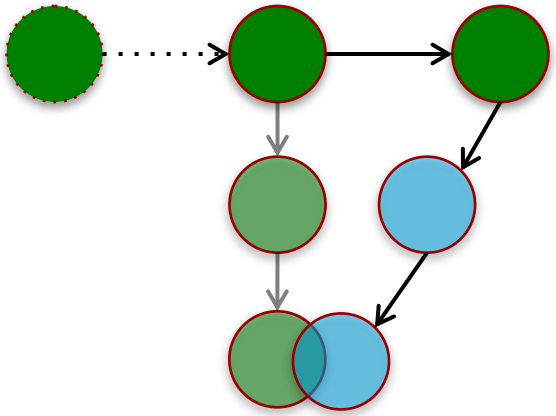
Dead Reckoning

- Assume velocity constant
  - Simulate the new position
  - Treats like physics object
- Generalize to other actions



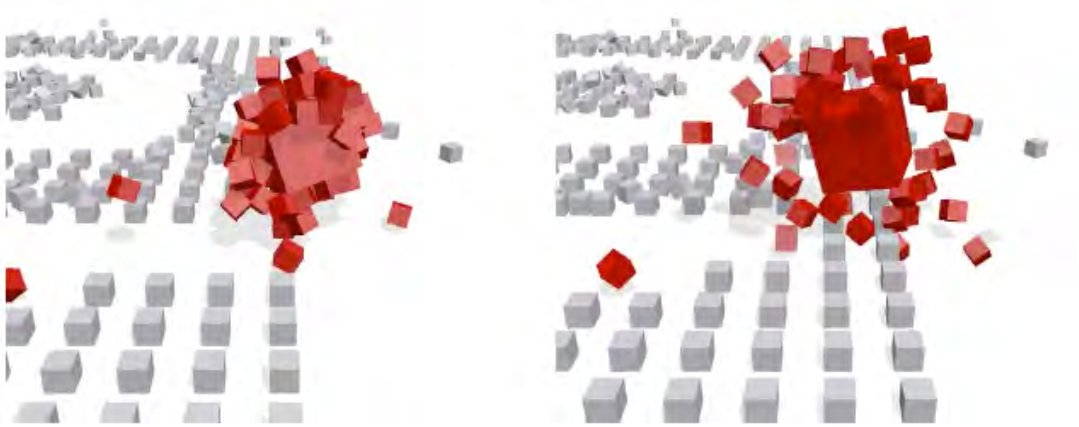
Error Smoothing

- Can interpolate late actions
  - Create simulation for action
  - Avg into original simulation
- Continue until converge



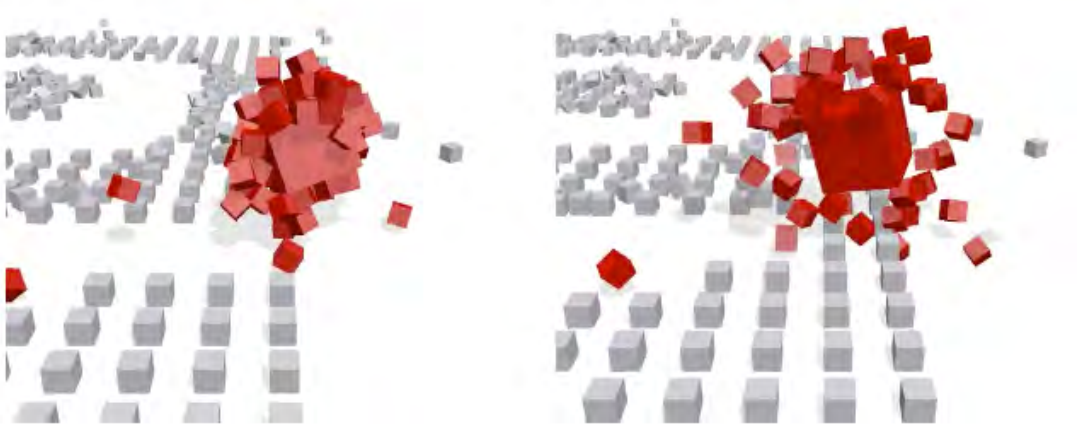
The Perils of Error Correction

Physics: Challenge of Synchronization



- Deterministic bi-simulation is very hard
  - Physics engines have randomness (not Box2D)
  - Not all architectures treat floats the same
- Need to mix interpolation with snapshots
  - Like error correction in optimistic concern
  - Run simulation forward from snapshots

Physics: Challenge of Synchronization



- Deterministic bi-simulation is very hard
  - Physics engines have randomness (not Box2D)
  - Not all ar
- Need to r
  - Like error correction in optimistic concern
  - Run simulation forward from snapshots

See today's reading

Physics: Challenge of Authority

- Distributed authority is very difficult
  - Authority naturally maps to player actions
  - Physics is a set of interactions
- Who owns an uncontrolled physics object?
  - **Gaffer:** The client that set in motion
  - Collisions act as a form of “authority tag”

Summary

- **Consistency:** local state agrees with world state
  - Caused by latency; takes time for action to be sent
  - Requires complex solutions since must draw now!
- **Authority** is how we measure world state
  - Almost all games use a centralized authority
  - Distributed authority is beyond scope of this class
- **Synchronization** is how we ensure consistency
  - Pessimistic synchronization adds a sizeable input delay
  - Optimistic synchronization requires a lot of overhead