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multiplayer games

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A multiplayer game is one where the actions of each participant influence the state of the game for all.

Multiplayer games can span a whole range of genres and they can be implemented with different underlying technologies and abstractions.

classify games

action cadence

- **turn based** (tic-tac-toe, worms, monopoly)
- **real-time** (age of empires, quake, table football)

Turn based games are easier to reason about and demand less of the server.

game state values

- **discrete values** (checkers, chess, connect 4)
- **continuous values** (quake, mario kart)

These call for different approaches in terms of animation and AI.
Game may simultaneously feature data of both kinds.

state visibility

- **completely open** (tic-tac-toe, snake)
- **partially hidden state**
  - RTS games: fog-of-war
  - card games: hidden hands from other players
  - FPS games: BSP + camera frustum determine what each player sees

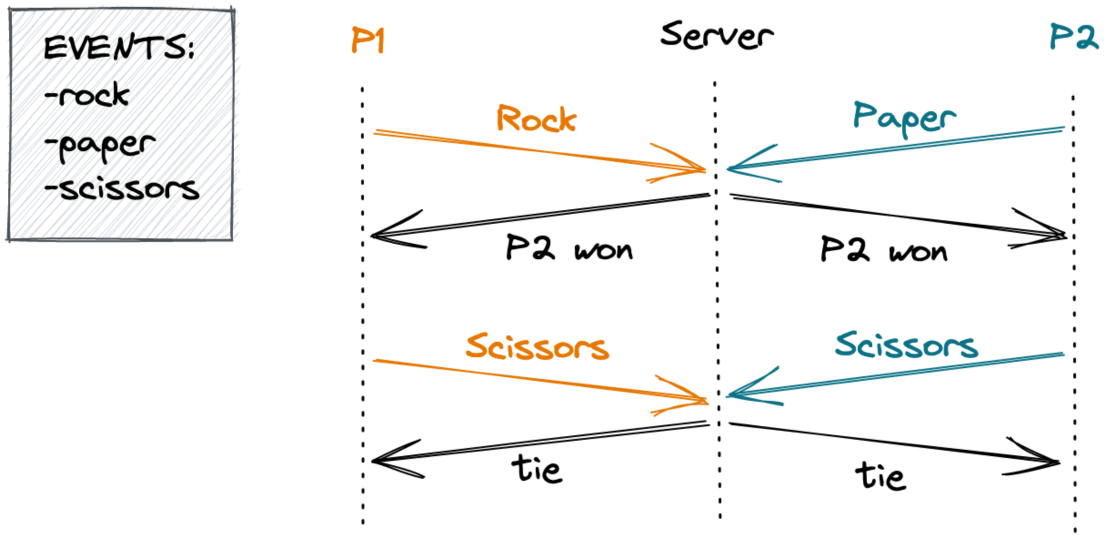
updating state and tick rate

game state update

Every game is expected to call a function which given the **current game state** and **new events** computes an **updated game state**.

On **turn based games** this function can be called **as each event arrives** and update state at the rate of arrival.
On **real-time games** a **constant period of time** is used. All events in that period serve as inputs to determine the next state.

rock paper scissors



tictactoe

EVENTS:
-play [x,y]

STATE:
next: P1
won:
finished: false
board:
[0,0,0
0,0,0
0,0,0]

msg content	msg dir	verdict	state update/error	
play([1,0])	p1 -> srv	OK	b:[1,2,1 0,0,0 1,0,2]	next:2
play([1,2])	p1 -> srv	NOK	ignored: not your turn!	
play([4,1])	p2 -> srv	NOK	ignored: out of range/invalid	
play([0,1])	p2 -> srv	OK	b:[1,2,1 2,0,0 1,0,2]	next:1
play([0,0])	p1 -> srv	NOK	ignored: occupied cell	
play([1,1])	p1 -> srv	OK	b:[1,2,1 2,1,0 1,0,2]	won:2 finished:true

realtime examples

	EVENTS:	STATE UPDATES:
RACING:	(accel%, brake%, steerDeg)	{ characters: [{id, pos, orientation, vel, acc}...] }
FPS:	(mouseDelta, mouseBtns, keysDown)	{ characters: [{id, pos, orientation, vel, acc}...], sounds: [{id, sample, pos, volume}...] }

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tick rate

The tick rate determines **how frequently the update function runs**.
A game with a 20 fps tick rate means it groups incoming player events in slots of 1s/20 = 50ms. After each tick, an update function with this signature is run:

```
(events, state) -> state'
```

As the result of this, clients are told the new state (subject to optimizations).

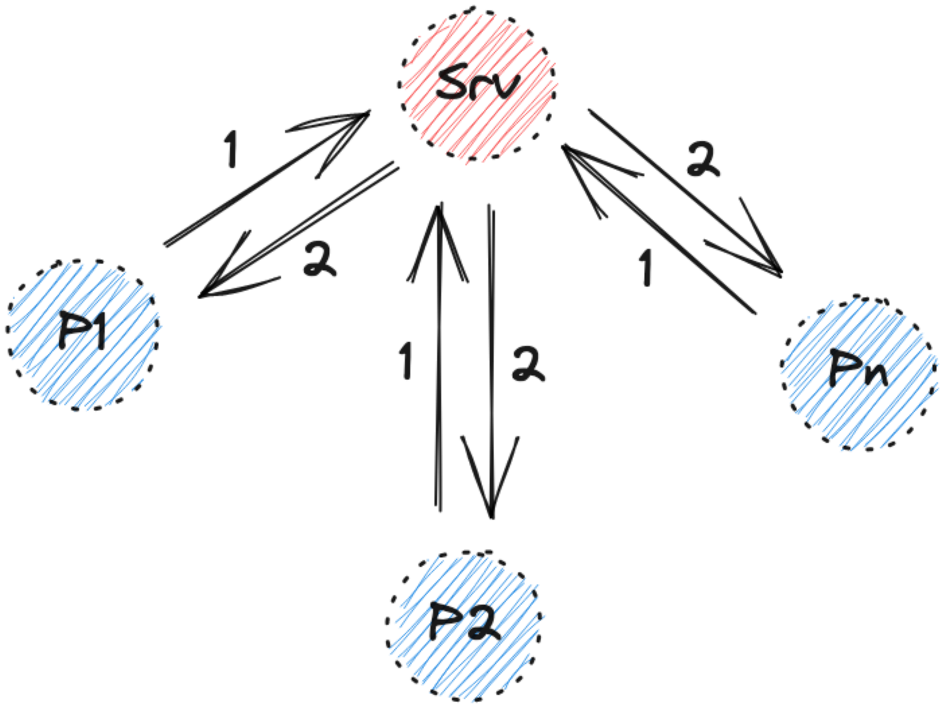
The tick rate **depends on the nature of the game**. Some genres allow for fewer tick rates and heavy use of interpolation while others need more frequent updates to be computed.

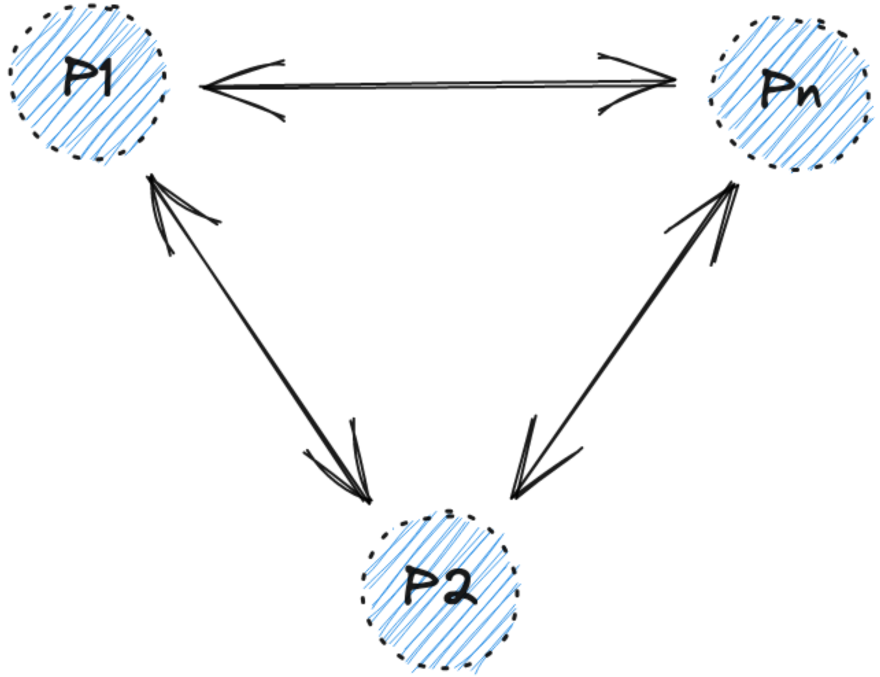
Topologies

multiplayer topologies

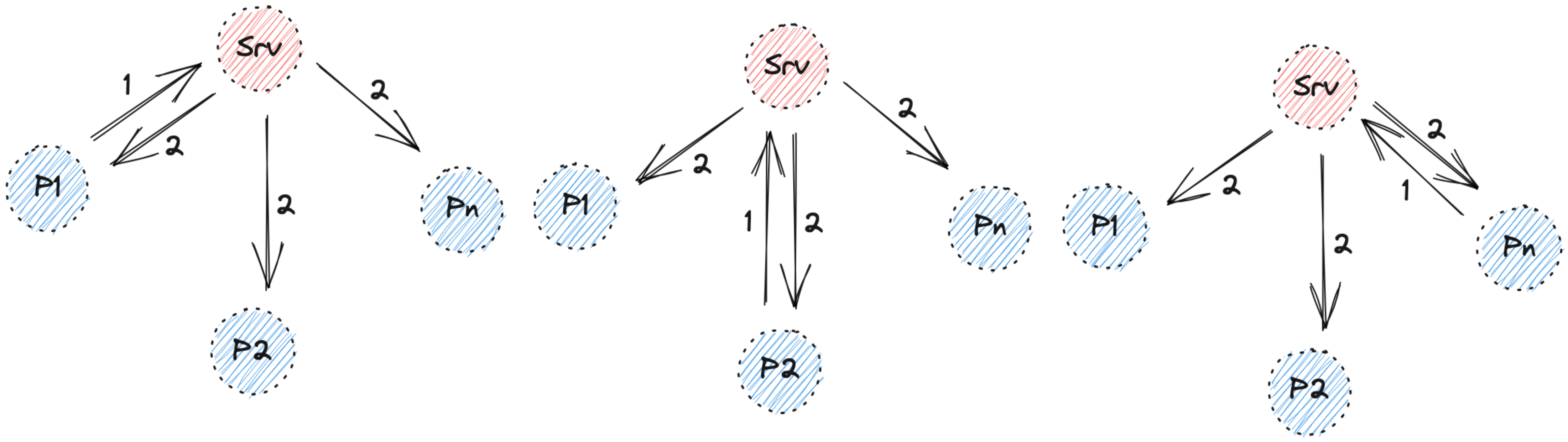
- **authoritative server** aka **client+server**
  all players/clients **submit their actions to the server**. game **state gets computed there** and distributed back to all players
- **relay** or **peer to peer**
  all players/clients have their own local views of the game state and **share their actions to others** so **others compute** them
- **authoritative with client-side prediction** aka **lockstep+rollback**
  players **submit their actions to the server** and also **run a local simulation**, used to optimistically render the player actions earlier (subject to corrections from server)

authoritative and P2P topologies





relay topology



topologies pros and cons 1/2

In **relay/P2P** the **evolution** of game state is **driven by each individual client**. Initial game states can differ. Incoming actions from remaining players ought to be respected but **it's impossible to enforce rules and order**.
Can be a **viable** solution for **slow-paced games** where entities belonging to one player don't directly impact the remaining players (ex: ghost cars in racing games).
Server work is limited to broadcasting events (relay) or none if P2P is used.

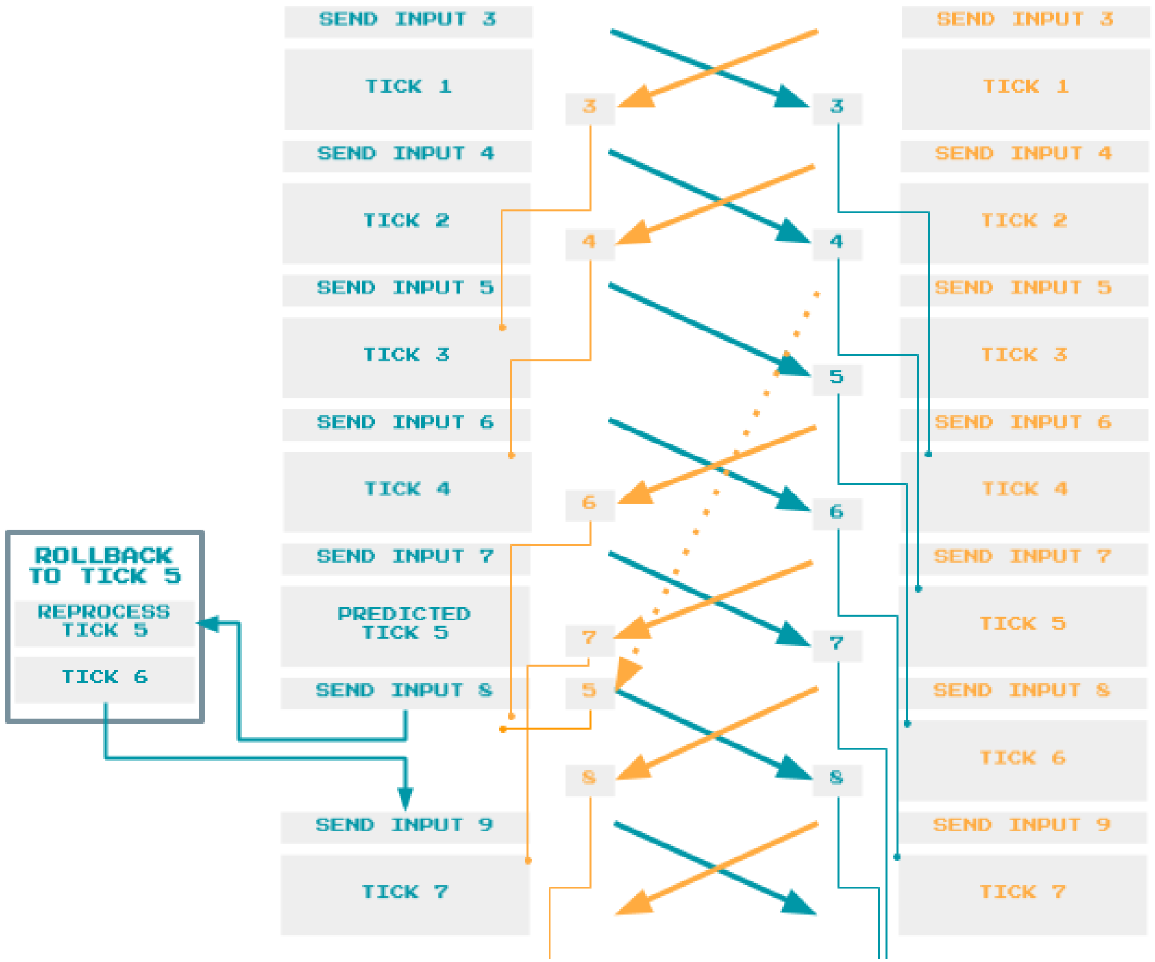
topologies pros and cons 2/2

In **authoritative** modes state and state evolution are **completely driven by a dedicated server**.

Authoritative is mandatory for any popular competitive game due to cheating.

Client-side prediction is standard for AAA fast-paced games and its as more challenging as more player-driven entities interact between players (ex: Rocket League simpler than Counter Strike)

lockstep + rollback



Other features

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lobbies and match making

People don't join games at the exact same time. They may not even know each other.

The **lobby** is a stage in the game where multiple players can **gather before the game starts**. It typically allows text **communication** and supplies a way for players to **invite other players** to take part in a shared game.

With **match making** the game takes care of **pairing up players into actual games automatically** according to a set of criteria.

They both solve the same problem but the latter relies on game services to do the heavy lifting.

scripting capabilities

Game servers tend to **run in combination** with well established **game engines** such as Unity, Unreal, Godot, Cocos2d, Gamemaker, Pixi, etc. Most of these support several programming languages.

External programming language support therefore became a popular feature for game servers frameworks, so developers can **use the same language on both sides of the game logic**, client and server.

A game server can do this by exposing a **clear API**, prepare logic modules, manage the language runtime and drive its code alongside its core. Ex: Nakama supports Go, JS and Lua.

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available network transports

- **non-web**
  - **TCP** (reliable and ordered stream)
  - **UDP** (unreliable discrete packets)
- **web**
  - **HTTP** (request/response)
  - **Server Side Events** (server driven messages)
  - **Web Sockets** (bi-directional messages)
  - **WebRTC** (for P2P and supporting audio/video streaming)
  - **WebTransport** (new standard, will unlock UDP-like comms)

Challenges

challenges 1/3

- **avoid disparate state** (skipping events, non-deterministic events processing order, different RNGs, rounding errors, incorrect logic in code)
- **minimize lag** (locally process ticks ahead, choose different topology, have animations easing change)
- **respect the tick rate** (hard with many incoming events and/or complex simulations)

challenges 2/3

- **cheating prevention efforts**
  - make sure not to send clients state they're not supposed to see
  - rate limit incoming events
  - ignore events with out-of-range values
  - ignore events with impossible sequences of events
  - defend against invalid messages breaking the server
- **provide matchmaking support** - expected to exist nowadays, very useful to help the game popularity network effect

challenges 3/3

- **support dynamic game server allocation**, so servers scale at peak popularity and we don't go broke
- **minimize server-side corrections*** - shares same problems as **avoid disparate state**
- **support many players in the same game** (MMOs, requires additional architectural changes, out of scope)...

* for games with client-side prediction

Existing Solutions

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commercial game servers

- Unity Multiplay: 1
- Epic Online Services: 1
- Microsoft Playfab: 1 2
- AWS Gamesparks: 1 2
- Photon: 1
- Improbable: 1

OSS game servers

- nakama 1
- colyseus 1
- lance 1 2 3
- glovjs 1
- ezyfox-server 1

To know more

- deterministic lockstep, playout delay buffer 1 2
- the physics of rocket league 1
- GGPO 1 2
- give me more! 1