Multiplayer Game Design

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October 16, 2019

1 Introduction

This design document is for a multi-player two-dimensional space shooter deathmatch that is playable up to 16 players. Figure 1 represents what the game could look like, it shows ships, their health-bars, some bullets and a space rock. With 16 players the gaming experience stays enjoyable. Beyond that game becomes confusing and other problems like spawn killing start to degrade the experience. Scaling the game beyond this would mean running multiple concurrent matches. For concurrent matches, multiple processes is used as servers for the distinct matches do not have any particular reason to share information between each other. To easily manage game servers between different hosts the system includes a server lookup server, which keeps track of online servers and transmits that information to clients.

The game server will use event based I/O-multiplexing to ensure quick response times to user actions. In addition to this common error compensation techniques are used to make the experience more pleasant. Asynchronous event based I/O is implemented in the program using the python asyncio library.

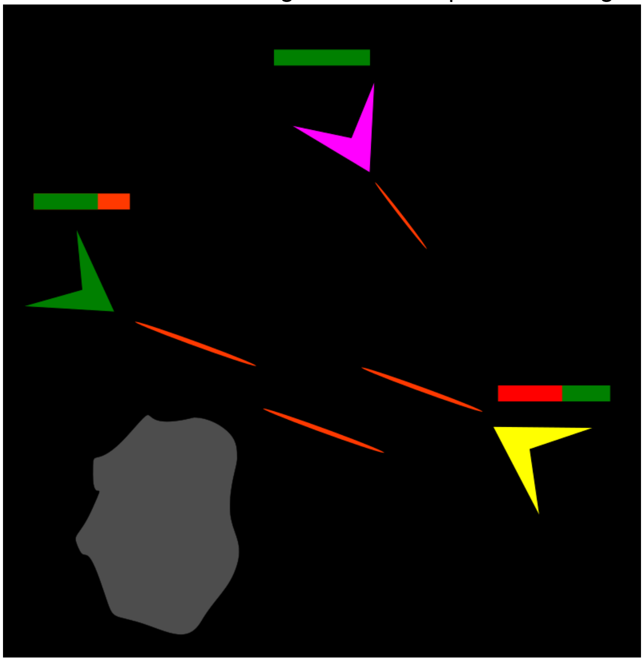
In this system both the server and the clients simulate the game state. If the simulations differ the server state rules over the client states. This is called client-side prediction and server reconciliation [2]. This is the common hierarchy, as doing the hierarchy other way enables cheating.

Reliability of the system is enforced with constant state updates between the clients and the server. The game state is sent 20 times in a second from the server to the clients, so if individual packet loss happens it's effects are mitigated in under a second. This can use a lot of bandwidth and cause congestion in the network, but it benefits the responsiveness and reliability of the server.

No error recovery is used as the data sent between clients and the server is highly time sensitive, and recovered packages would probably lose their relevancy during an extra round-trip time. Error correction could maybe be used, but the overhead might hinder responsiveness of the game and use more bandwidth. For these reasons, reliability of this game is based only on the constant state updates and error compensation.

Clients can load for the game that change the look and feel of the ship and the map background. These downloads use different mechanisms than the game-play networking. The resources are served with regular TCP file transfer

Figure 1: Concept art for the game



methods. The loaded assets are validated using checksums. Currently only the ship image can be downloaded and no checksum is implemented.

The design does not assume that the clients can connect to each other because of the strict NAT-types, but it the server must be able to receive and send UDP-traffic to all participants. So NAT and Firewall settings for the server side must be configured correctly.

2 Game logic and engine

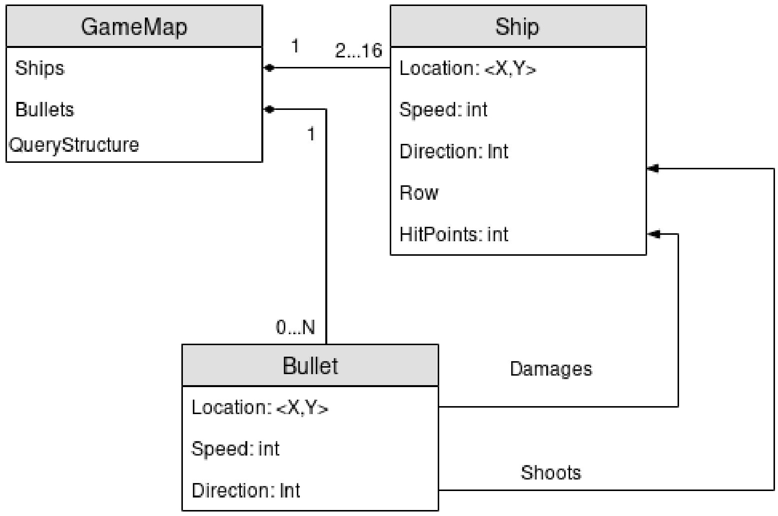
The game consists of a map, player controlled ships, and bullets. The map is a empty area of space in which the ships can battle out. The map has limited size and if a player ship hits the border it will be damaged.

The player ships have 10 hit-points. One hit-point is subtracted every time the ship receives damage. The goal of the players is to destroy as many other players as possible. Players can damage opponents ships by shooting bullets. The ship data model contains information about their hit-points, heading and speed.

The bullets are simple data-objects that spawn when a ship shoots. The bullet has static speed and direction, along with location information. This allows both the client and the server to simulate bullet movements concurrently. Figure 2 displays simple domain model of the game logic.

The map object contains a hash-map data-structure in which the each key represents a map dot on the map that contains something. If some key contains two values it is a collision and then the damage calculation is preformed on the object.

Figure 2: Simple model of the game logic



The game engine aims to constantly run the game at 60 game cycles per seconds and it updates the state to server 20 times per second. A game cycle contains of the following actions; apply server state every third cycle, register user input, check collisions, calculate hit points and send a input to the server.

3 Client-server communications

In this application clients and the server communicate with each other trough UDP. UDP is preferred TCP because this application is very time sensitive. In this domain it is better to just lose packets than try to retransmit. The retransmitted packages will be already out of date when they are finally received, hence retransmitting only furthers network congestion.

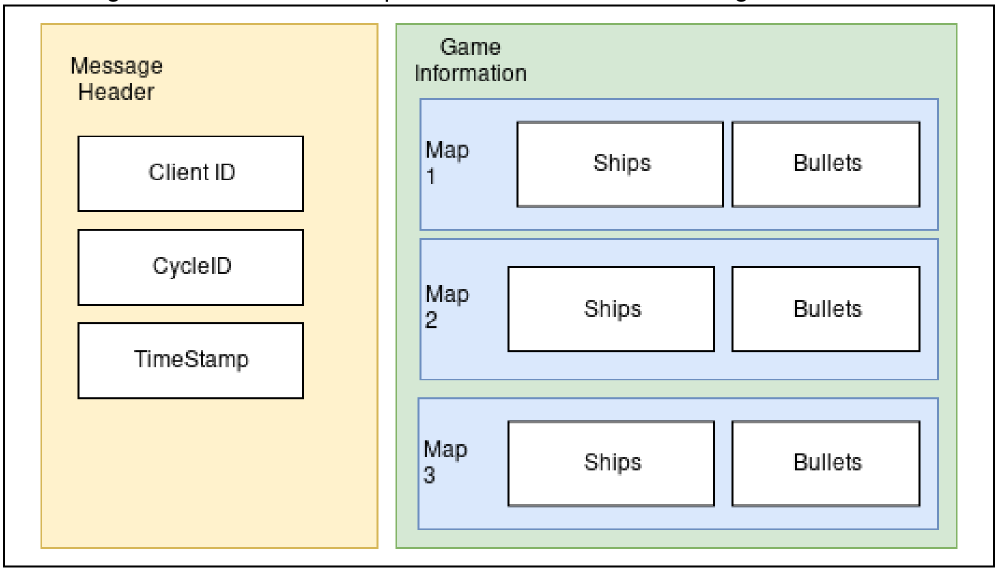
With UDP reliability must be implemented at application level. In this application the client and server game engines try to simulate the game state as best they can with the information at hand. This helps with small amounts of sporadic packet loss, but this practice is weak against error bursts.

The game state is transferred between the client and the server in JSON-format that follow the description of the message frame shown in figure 3. The message frame contains a small header for transmitting necessary information that is not obvious from the game state on its own.

Client ID is used to identify the client. Cycle ID is used mostly for debugging purposes. It can be used to determine if client or server software start to miss tick-time deadlines.

Time-stamp is used in entity interpolation. When a client sees other ships in the game those are actually the other ships from the previous tick-time. Time-stamp is also used to lag-compensate hit detection at the server. The lag is caused by the entity interpolation, so effectively every client sees the other ships 50ms in the past. With a time-stamp the server can reconstruct every

Figure 3: Visualisation of prosed server-to-client message frame



client state between ticks and treat them fairly [1]. The time-stamp can also be used to calculate latency between the client and the server. The latency figure can be used to make the lag compensation even more accurate. If the game would be expanded to host multiple concurrent matches a match identifier field is added to the header.

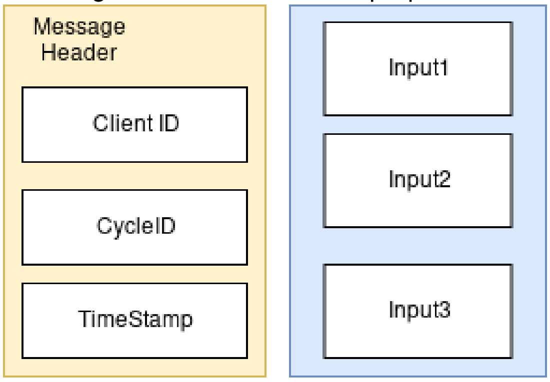
I ended up giving each input event its own timestamp and duration. That way the server can reconstruct a timeline of input events from all clients and simulate them in order. I also removed cycleId as it served no purpose. The client can put as many input events to the message as it manages in the time frame.

The game information contains the game state of the past 3 ticks. The client needs these for entity interpolation. The client sends its input information to the server 20 times a second. As it is intended that the clients run at 60 cycles per second it sends the input information for all the cycles. This is visualised in figure 4.

In the original design I devised that the clients get the state for the past 3 ticks from the server to perform entity interpolation. This did not make much sense after I decided to use time based physics instead of tick based physics. So I ended up sending the input commands for other clients from the server to all clients, and reuse the same input handling logic on the client-and server-software alike. Simulating all inputs on the clients seems to have decent interpolation results, given that all clients sustain near 60 frames per second.

Network error burst will cause something that gamers usually refer as a ‘lag spike’, in which the controls issued by the player do not get the desired outputs. When the client states are synced with the server state after a burst of packet loss players will experience phenomena usually called ‘rubber-banding’, in which the player ships are moved to a location correct in the servers point of view. This makes the game less enjoyable, but keeping the client state as

Figure 4: Visualisation of proposed client-to-server message frame



the correct state would open a huge can of worms when it comes to cheating possibilities.

The client joins the match hosted by the server using a special handshake message. When this message arrives at the server the client is added to the match, if there is still room in the 16 player quota. The client has knowledge of some servers and can try to connect to every one of them.

If client does not update its state to a server for 10 seconds it is kicked out of the server.

4 Server architecture

The server will follow event driven architecture. There is two kinds of events in this application, the messages coming from the clients and the tick-timer of the server.

Event handler for client messages applies the changes of the client state to the server state if those follow the game rules. Event handler for tick-timer will send the server state to all clients. Performance of the server is dependent on calling non-blocking I/O-calls especially for the sending the state to the clients.

So to implement this design the programming environment needs to support asynchronous I/O and event loops. Despite this the server responsiveness will slow down as player count increases. To meet the goal of 20 updates per second, the server will have to validate the 16 player game states and send the correct game state back to the clients within 0.05 seconds. That leaves 3.15 milliseconds to validate player game state, assuming that those arrive on time. These strict time limitations make it appealing to run concurrent matches in separate processes, given that the host system has the network resources to handle multiple matches.

In this system there is an additional micro-service that only keeps track of the online-game-servers and gives this list to the clients. From this list the client can see the player count and ping of each server. The server has a component that sends its information to the game-list-server, containing name, ip-address, and player count. The game servers send heartbeat updates to the lookup server every 15 seconds through TCP. If a game server does not get a heartbeat signal through in 30 seconds the lookup server will determine that it is off line.

5 Downloading game settings

The clients can download new assets to the game, from a separate asset server that uses TCP-for transferring the assets to the client. This functionality is implemented in the resourceServer.py module.

The assets contain but are not limited to new ship designs, new background textures and different ambient music tracks. The user can select assets through a settings menu. At the moment users can download different styles of a ship texture through a simple text interface.

The client source code contains MD5-checksums for all available assets, that are used for end-to-end error detection and recovery. If the checksum does not match with the one calculated from the received data the user is prompted and the client retries the download. Due to lack of time the MD5 checksums are not implement at the moment.

References

[1] Bernier, Yahn W.: *Latency compensating methods in client/server in-game protocol design and optimization*. `https://developer.valvesoftware.com/wiki/Latency\_Compensating\_Methods\_in\_Client/Server\_In-game\_Protocol\_Design\_and\_Optimization`, visited on 2019-10-03.

[2] Gambetta, Gabriel: *Fast-paced multiplayer*. `https://gabrielgambetta.com/client-server-game-architecture.html`, visited on 2019-10-03.