Networking in the Real World

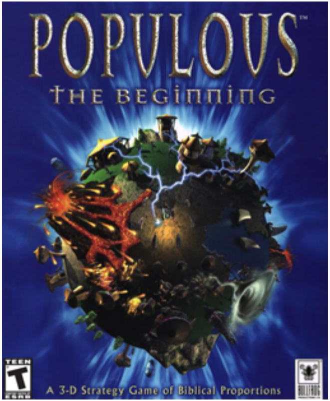
Ben Deane

3rd March 2015

Who is this guy?

- Ben Deane
- Programmer at Blizzard on the Battle.net team
- Lifelong* network game programmer

What has he done?



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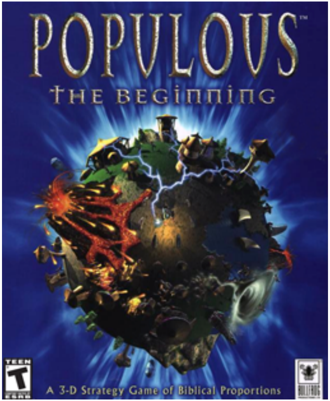

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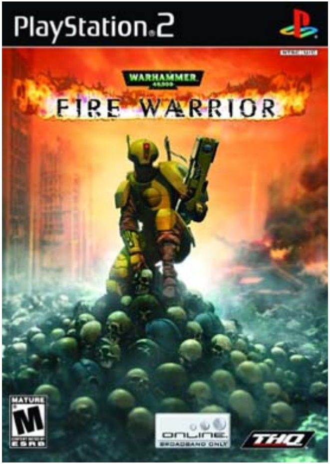

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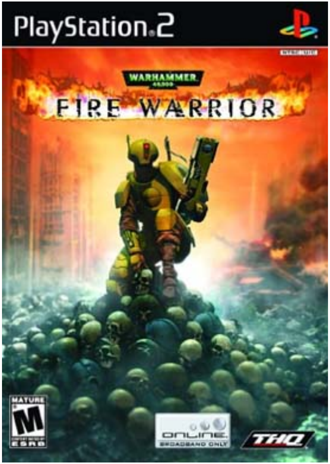

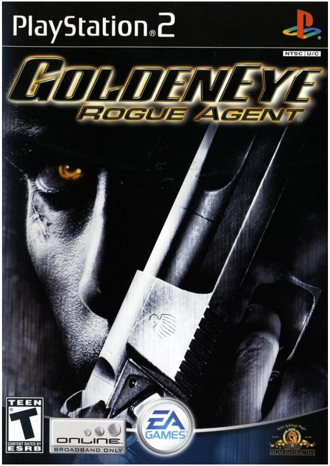

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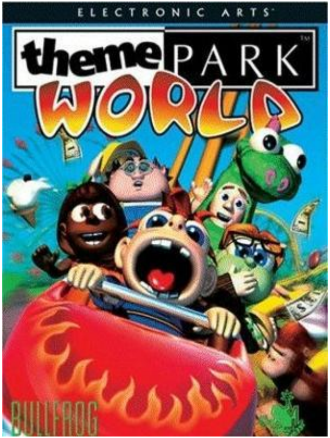

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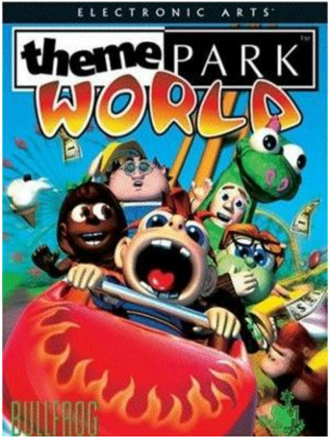

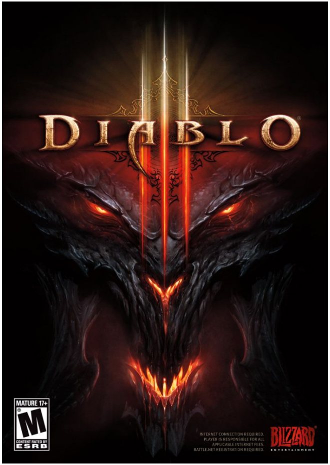

What's in this lecture?

- Real world examples
- Practical advice
- Some war stories
- Spartan slides

"Experience is simply the name we give our mistakes."

– *Oscar Wilde*

Why Network Programming?

Year	CPU (MHz)	Memory (MB)	Typical RTT (ms)
1995	90	8	300
2000	400	32	300
2005	1400	256	300
2010	2660	4096	300
2014	3330	16384	300

- Networking programming stays interesting and challenging
- Hiding latency is the constant problem to solve
- Non-network programmers just discovered concurrency?

Real World vs Academia

The Real World is what you learn but also:

- messy
- dealing with edge cases
- cutting corners
- taking advantage of hardware

TCP vs UDP

- Your most basic latency-affecting decision
- Game design and genre influences this

TCP vs UDP

TCP

- Connection, stream-oriented

UDP

- Connectionless, packet-oriented

TCP vs UDP

TCP

- Connection, stream-oriented
- 20-byte header

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- Immediate send

TCP vs UDP

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- Connection, stream-oriented
- 20-byte header
- Guaranteed in-order
- Nagling
- Socket per connection

UDP

- Connectionless, packet-oriented
- 8 byte header
- Best-effort
- Immediate send
- Single multiplexed socket

TCP or UDP?

- Your data is usually ephemeral
- It doesn't matter if one or two packets get dropped
- UDP can do NAT traversal
- UDP packet overhead is lower

Synchronizing Time I

Method 1. An NTP-like algorithm

- Estimate RTT with smoothing
- Adjust clock by (time on wire)/2
- Part of connection establishment
- Sync to epoch (eg. start of level)

Synchronizing Time II

Method 2. Iterative approach

- Client guesses time on server
- Server tells client how wrong it is
- Client adjusts its clock and repeats
- Stop when you're within tolerance

Network topologies

Peer-hosted

- single authority

"True" peer-to-peer

- distributed authority

Network topologies

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- single authority
- 2x RTT
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- failures affect one player
- "free" consensus
- one player needs upload BW

"True" peer-to-peer

- distributed authority
- 1x RTT
- n(n-1)/2 connections
- failures affect everyone?
- "free" host migration
- everyone needs upload BW

Basic FPS Network Model

- Client-server/peer-hosted
- Time-synched to within a few ms
- Object state is transferred
- Clients converge to the true state
- 90% of data is for movement
- Semi-guaranteed protocol over UDP

Typical FPS Choices

- Two bullet types
- High fidelity human animation (=> head shots)
- Relatively few active objects at a time
- High render rate, low logic rate
- Available headless server
- Simple/Nonexistent AI

Example Semi-Guaranteed Protocol

- Entity-component model
  - Movement/Position/Rotation
  - Animation state
  - Health/Armour/Death state
- Components are marked dirty as their state is updated
- Components map to network "channels"
- Network channels are given priorities

Constructing Packets

- Keep dirty components in a priority queue
- Periodically fill a packet by priority
- Max packet size = 548 bytes
- Anything left out gets increased priority

ACKing and NAKing

- Each packet contains a sequence number
- When components are serialised they remember the sequence number
- Each packet header includes ACKs for previous packets received
  - a sequence number and a bitfield of previous acks
  - handle sequence number wraparound
- Any gaps in the ACK stream are implicitly NAKed
- Components from NAKed packets have their data re-dirtied

Compressing data

- Conserving bandwidth is important
- Bitpacking protocols are common
- Range data types
- Floating point types can be truncated
- Or quantize position in level
- 4x4 matrices are wasteful
- Rotations can be heavily quantized

Other issues

- Some things need in-order delivery
- Object creation/destruction events
- Some objects can do parallel simulation
- Others must be kept up-to-date

Race conditions

Bob's machine

Alice's machine

Race conditions

Bob's machine

Alice's machine

- Bob has 10% health.

Race conditions

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- Bob has 10% health.
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- Bob has 10% health.
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Race conditions

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- Bob dies.

Bob's machine

- Bob has 10% health.
- Bob picks up a health pack for a 50% health boost.
- Alice hits Bob for 20% damage.
- Bob has 40% health.

Race conditions

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- Bob dies.

Bob's machine

- Bob has 10% health.
- Bob picks up a health pack for a 50% health boost.
- Alice hits Bob for 20% damage.
- Bob has 40% health.

What to do about this?

Race conditions

- Some things are problematic for races
  - eg. Health/Death
  - Divergent simulations would be bad
- You can use an accumulator model
- Take care to deal with overflow

Latency Hiding: Simple Stuff

- Clients can do simple display feedback
  - Hit animations
  - Audio
  - Blood splats
- Some things aren't going to fail
  - eg. Decrementing ammo

Predict the future

Interpolation/Prediction

Predict the future

OR (and?)

Interpolation/Prediction

Predict the future

OR (and?)

Interpolate the past

Interpolation

- Simple lerps
- Failure modes
  - Players stop
  - Warping forwards
- Take corners close
- Fundamentally a graphical/display approach

Prediction I

- Dead reckoning
- Position/Velocity/Angle
    - Acceleration
    - Rotational velocity
- Failure modes
    - Players run into walls
    - Warping back
- Take corners wide
- Fundamentally a game state/logic approach

Prediction II

- Client must reconcile its position with the server position
- Server position is in the past
- Client must rewind a little and replay recent input
- Mostly this results in seamless fixup

Prediction III

- A client can predict itself…
- Use this information to know its actions are causing divergence
- Therefore when to send an update
- You can mix a timeout with this also

Subsystem Considerations

- Play nice with the physics engine
  - Moving things into each other is a bad idea, you're not going to have a good day
  - A capped timestep is essential for your debugging sanity
  - A continuous collision system is usually necessary
- Animation tricks
  - A headless server need not pose characters until necessary

More on Update Logic

- Variable update frequency
  - Proximity
  - Velocity
  - Role (eg. target/team)
  - Visibility (PVS)

Parallel Simulation

- Some games (eg RTS) have too many objects to sync
- Input passing
- Parallel simulation

Parallel Simulation Problems

- Random events
- Camera-dependent events
- Floating point machine differences

E-sports and Fairness

- Lockstep model is old but still important
- Fairness trumps latency hiding
- High level RTS gameplay is twitch gameplay

Bug Story

Populous: The Beginning Network Model

Server

```
while (!game_over) {
  recv_client_inputs();
  send_gameturn();
  simulate();
}
```

Client

```
while (!game_over) {
  if (receive_gameturn()) {
    simulate();
  }
  render();
  send_input();
}
```

Spot the bug!

Bug Story

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while (!game_over) {
  while (receive_gameturn()) {
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  render();
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}
```

`if` changes to `while`

Bug Story II

Goldeneye: Rogue Agent

Bug Story III

Firewarrior NAT negotiation

Thanks

The Real World: like Academia, except with smoke & mirrors & cutting corners & messy stuff.

Thanks for listening

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Slides & notes available at

`http://github.com/elbeno/networking-in-the-real-world`