What Can Games Learn From Security Research?

Wu-chang Feng

On-line Games

- A multi-billion dollar industry
  - Some cash cows

Warcraft/Starcraft

Half-Life/Counter-Strike

World of Warcraft

Age of Empires

Battlefield

Lineage

Cheating

- Achilles heel of the gaming platform
  - Causes legitimate players to quit
  - Creates bad word-of-mouth to discourage new players
  - Wrecks virtual economies

Hacking

- Achilles heel of the Internet platform
  - Causes legitimate users to lose productivity
  - Creates bad word-of-mouth to discourage new uses
  - Wrecks real economies and business models

Observation

- A lot of research and effort has been expended solving the hacking problem
- R&D from the computer security field may be helpful in preventing cheating in on-line games

Goal

- Find and apply security research in novel ways to games
- 3 projects
  - Using cryptographic protocols to prevent cheating
    - Mitigating information exposure in RTS games
  - Applying platform integrity tools to detect cheating
    - Tamper-resistant, hardware-based game measurements
  - Creating new game architectures using cryptographic primitives
    - Public-server MMORPGs

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Background

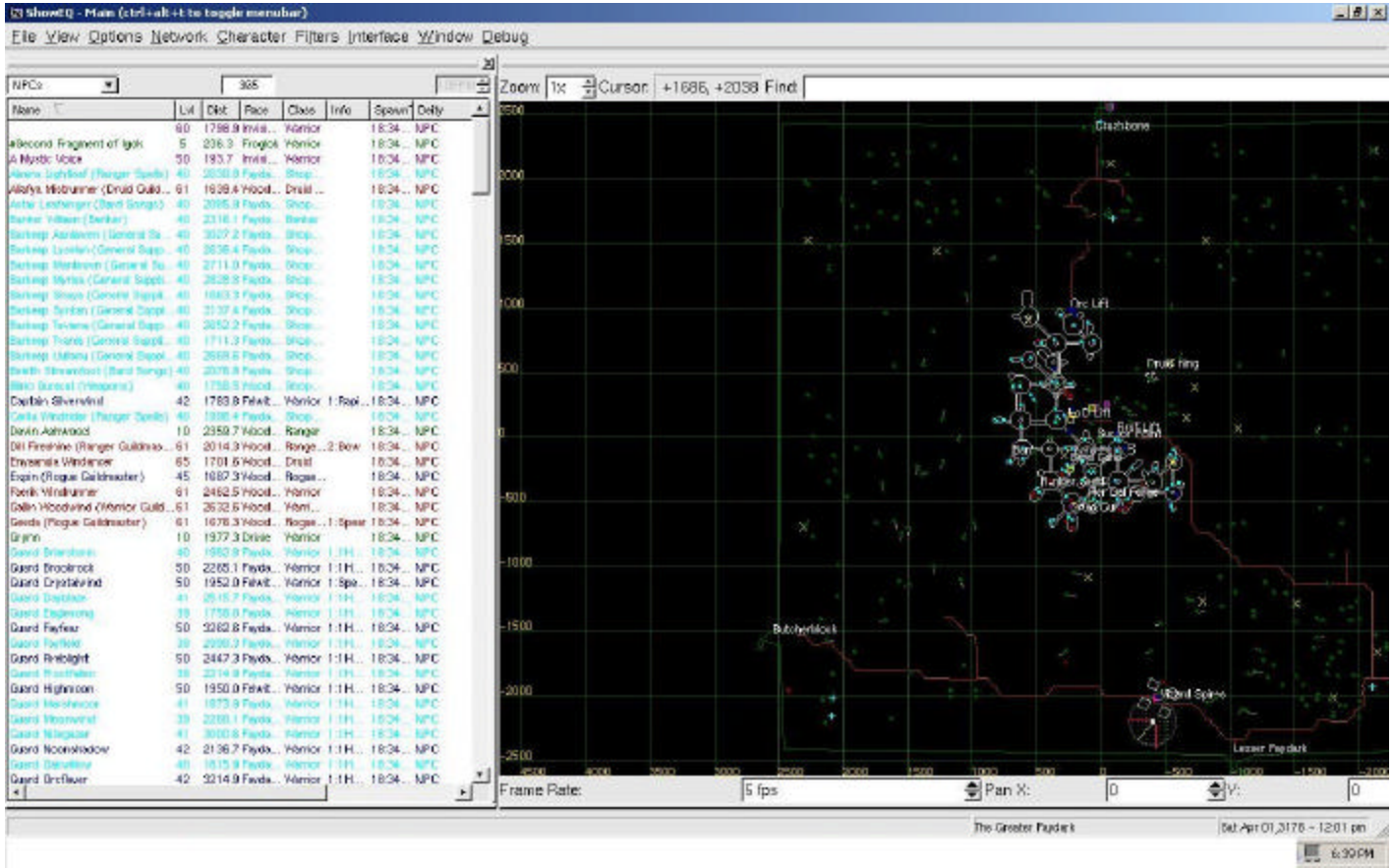
- Information exposure cheats
  - Display information player should not see
  - Server or peer sends complete information to client
    - Other player locations
    - Chest contents
    - Often due to performance reasons
  - Client code expected to hide information that is not supposed to be seen by player
  - Cheat reveals secret information to player

Examples of information exposure

- Wallhack in FPS games
  - Quake 4 – released 10/18/2005
  - Call of Duty 2 – released 10/25/2005
  - Cheats for both in 11/2005

Examples of information exposure

- Maphack/Chesthack in MMORPGs
  - ShowEQ for EverQuest
  - Display all entities and equipment on a map



Examples of information exposure

- Maphack in RTS games
  - Warcraft3

Examples of information exposure

- Maphack in RTS games
  - Warcraft3 with Maphack
  - Reveal map and enemy units

Solving information exposure

- Remote rendering
  - Expensive, slow
- Data culling
  - Still expensive, but possible (Cheating-Death)
- Problem with both approaches
  - Requires a trusted game authority
  - Does not work for peer-to-peer games
    - e.g. Real-time Strategy games such as Warcraft 3
    - No trusted third party
    - Players do not trust each other and game performs identical and complete simulations on both ends
  - Must hide information while ensuring cheat-proof play
    - Security protocols to the rescue!

Trick #1: Zero-knowledge proofs

- Determine if two units share the same location without revealing their location
  - Perform cryptographic exchange to determine if a unit is in the same region as an enemy while leaking no information about your position
  - Information revealed to both entities only when it should be

Baughman, Levine, “Cheat-proof Playout for Centralized and Decentralized Online Games”, INFOCOM 2001

Trick #1: Zero-knowledge proofs

- A, B have two units located at positions p_a, p_b
- Zero-knowledge proof to determine if $p_a == p_b$ without revealing p_a or p_b to opponent
  - A, B create secret keys k_a, k_b
  - A $\leftrightarrow$ B agree on a random number r
  - A $\leftrightarrow$ B exchange encrypted positions
    - A ® B: $(r + p_a)k_a$
    - B ® A: $(r + p_b)k_b$
  - A $\leftrightarrow$ B encrypt and exchange each other's messages again
    - A ® B : $((r + p_b)k_b)k_a$
    - B ® A : $((r + p_a)k_a)k_b$
  - A, B compare what they sent with what they received
    - If equal, $p_a == p_b$

Trick #1: Zero-knowledge proofs

- Problems
  - Scaling as number of secrets increases
  - Latency (multiple round-trip times per proof)

Trick #2: Bit-commitment

- “Sign” and send hashes of moves using secret key that is disclosed after game
  - Reveal game information and moves in the clear when other client is entitled to it
  - Replay game to ensure cheating did not occur

Bit commitment example

- Peer-to-peer Battleship

1

A **knows** B's location

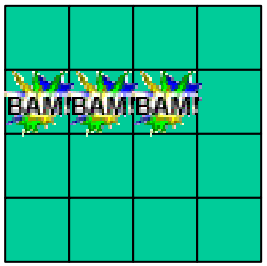
2. A fires and hits

Shoot(1,2) → hit

Shoot(2,2) → hit

Shoot(3,2) → hit

3. A cheats, A wins



"Just lucky I guess"

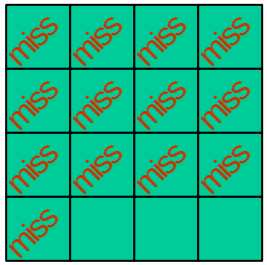
1

A ***doesn't*** know B's loc

2. A fires, B lies

Shoot() → Shoot() → Shoot() → Shoot() → Shoot() → **miss**

3. B cheats, A loses



"Just unlucky I guess"

Bit commitment example

- Securing peer-to-peer Battleship
  - Pre-game
    - Exchange keyed cryptographic hashes of ship location using secret key
    - Commits players to a specific location without revealing it (bit commitment)
  - In-game
    - Send and receive shot coordinates in the clear along with whether opponent's last shot hit or missed
    - Opponents can lie about hits/misses here
  - Post-game
    - Exchange secrets and initial ship location
    - Verify opponent's integrity by checking all the evidence of shots vs. replies

Our work

- Apply bit-commitment to address information exposure cheats in real-time strategy (RTS) games
  - Warcraft 3

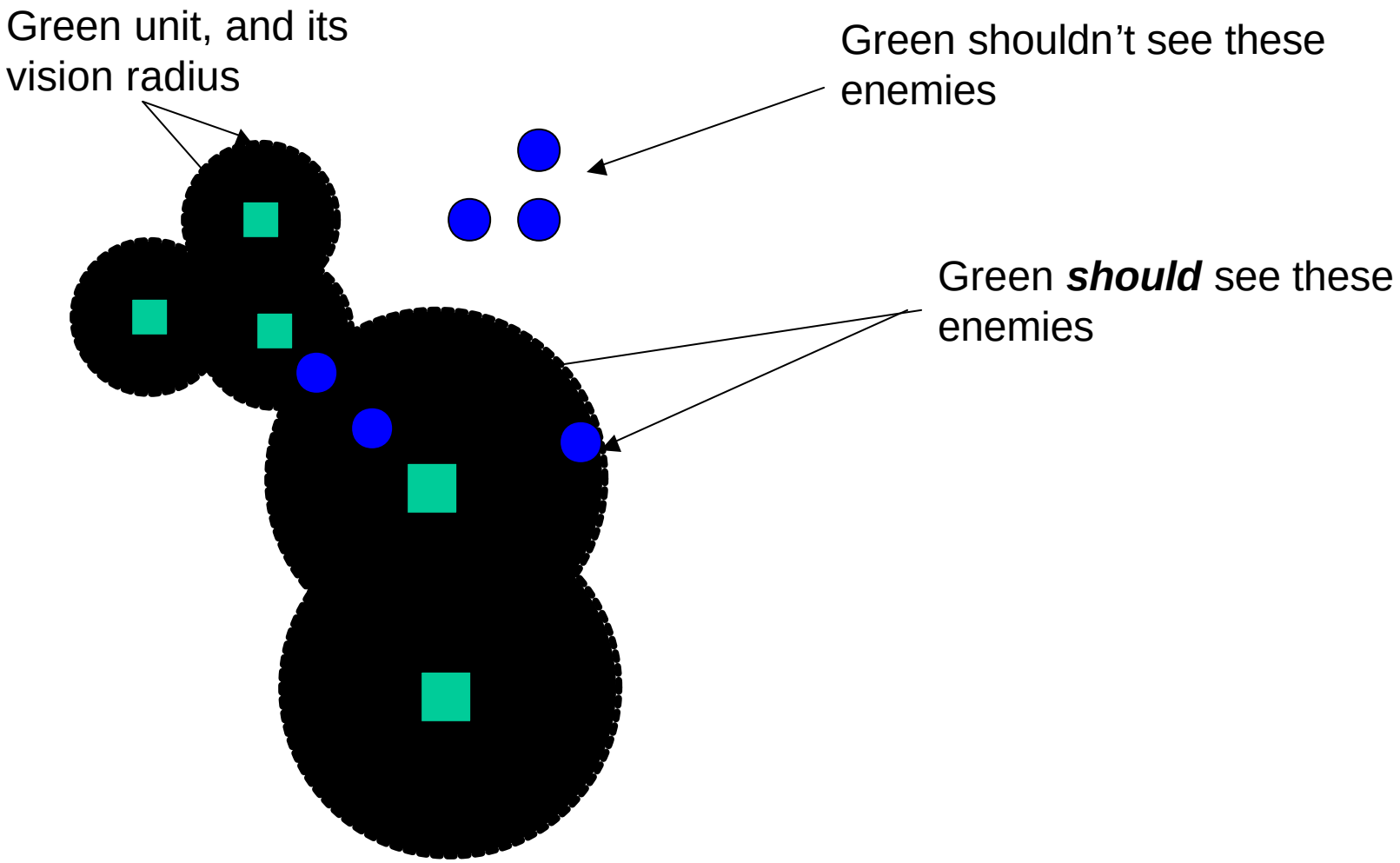
Background

- RTS games
  - You and your adversary build and control opposing armies
  - Army units balanced like rock, paper, scissors…
    - Knowing opponent's armies makes it easy to win
  - Rely on "*fog of war*" to make game interesting
  - Have hundreds of secrets that change every moment
    - Unit type and unit location
    - Zero-knowledge proofs not feasible
    - Contrast to Battleship with one secret per player per ship!

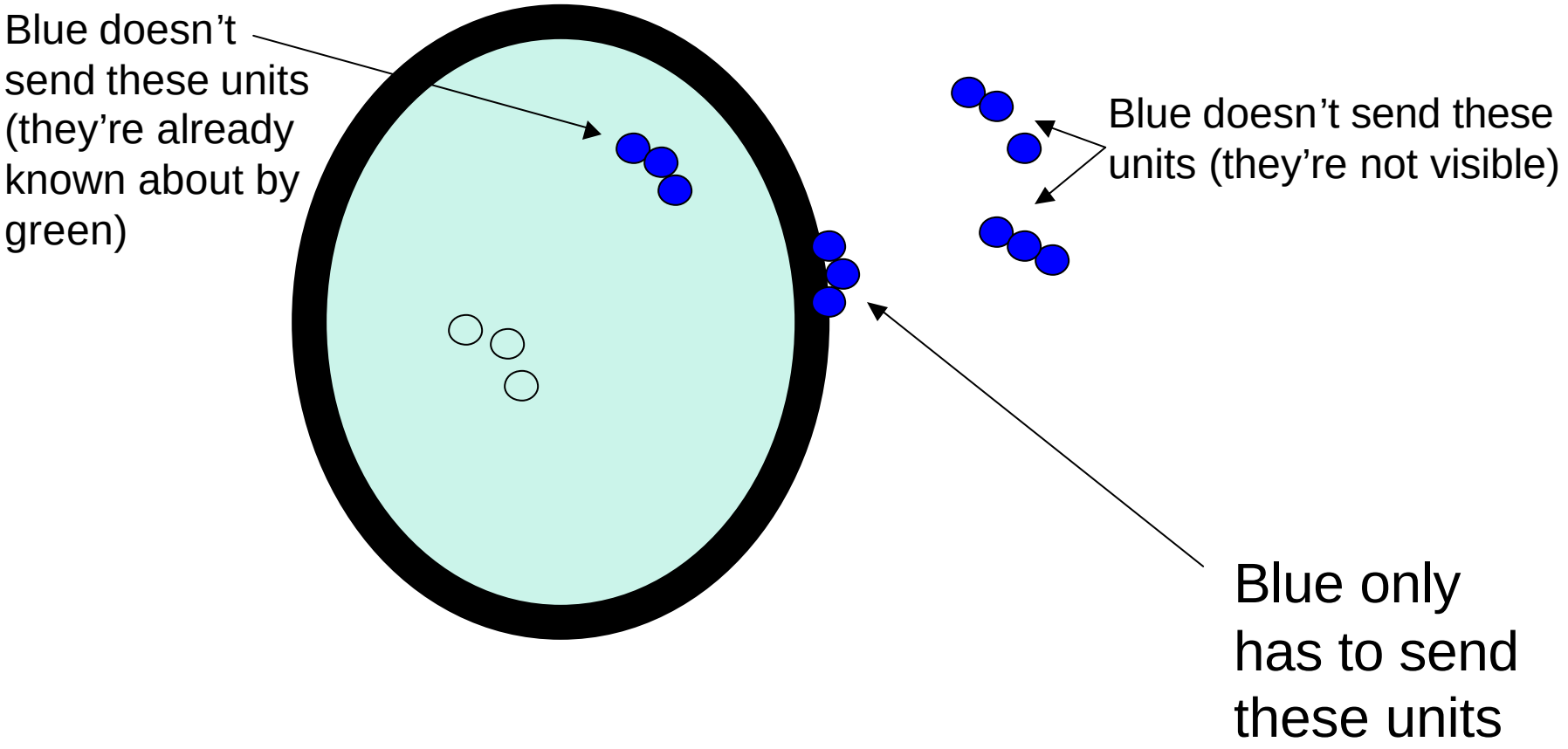
Current RTS network protocol

- Exchange initial game state and all subsequent mouse clicks
- Each player simulates identical copies of game
  - PRO: no one can lie about what units they have
  - CON: each player knows state of the entire game
  - Just like Battleship

How it should work



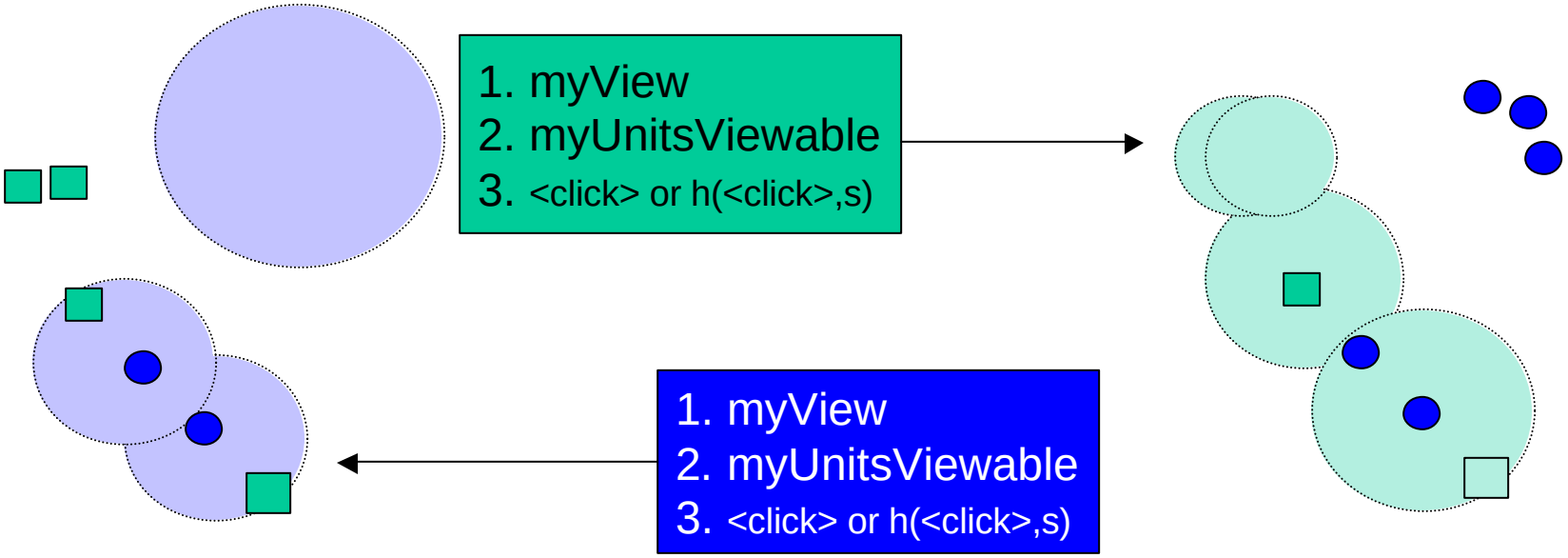
How it should work



Applying bit commitment to RTS

Key idea: You and your opponent only know each others "view area" not each others units

```
if (<click> is in oppView)
  send <click>
else
  send hash(<click>,secret)
```



Modified RTS network protocol

- Pre-game
  - Create your secret *s*
  - Generate initial game state *igs*, send *h(s,igs)*
- In-game
  - Each time slice, send (and receive)
    - Your viewable area
    - Either your move *m*, or, if it's invisible to him, *h(s,m)*
    - If one of your units just entered his area, send that unit
- Post-game
  - Exchange your secret, initial conditions, and all hidden moves throughout the game
  - Verify opponent's integrity by simulating the game rapidly with the (now known) hidden moves

Issues

- Not all information is concealed
  - Old way: know everything
  - New way: know only viewable areas
  - *How much* information does the new way conceal?
    - Use Shannon's uncertainty to measure
- Increased network requirements
  - Old way: bandwidth = number of clicks
  - New way: bandwidth = clicks or hash of clicks, viewable areas
    - Use Warcraft 3 tournament replays to measure

C. Chambers, W. Feng, W. Feng, D. Saha, "Mitigating Information Exposure to Cheaters in Real-Time Strategy Games", NOSSDAV 2005.

Adding incremental verification

- One-way hash chains with delayed key disclosure
  - Each player creates hash chain
    - h_n, h_{n-1}, … h_2, h_1, h_0
    - h_n=random secret and h_{n-1}=H(h_n)
    - Exchange h_0
    - Round i, commit moves with h_i, reveal h_{i-1}
  - Each unit given a random ID = N
    - While unit “hidden”, unit moves are committed by sending H(N),H(<click>, N, h_i)
    - Reveal N when unit appears
    - Opponent verifies units incrementally

Adding non-repudiation

- How to prove cheating to a 3rd party?
  - Use public-key cyptography: message signatures
    - Digest each message and encrypt the digest with private key
    - 3rd parties digest each message and compare with decrypted digest
  - Ideally public keys for this stored at game's authentication server

Adding to other games

- Easily applicable if game is tolerant to
  - Added bandwidth overhead
  - Added CPU overhead
- Examples
  - Board games
  - Card games

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Cheats are prevalent

- Wallhacks
- Maphacks
- Macros
- Item duping
- Disc hacks
- Aimbots
- Collusion
- Speed hacks
- Chest hacks
- Auto looters
- Gamebots
- Rejoin hacks

Cheats are complex

- How they cheat
  - Read memory to expose information
  - Modify display path to add visual aids
  - Inject protocol messages
  - Modify game textures and models on disk or in memory
  - Programmatically play game on behalf of player

Cheats are complex

- How they hide
  - Polymorphism
    - Disassemble signatures being checked to thwart file and memory signatures
  - Privileged mode execution
    - Run in kernel to prevent anti-cheat detection
  - Run-time code patching
  - Direct kernel object modification
  - Selective disabling
    - When anti-cheat code is about to run
    - When new anti-cheat distributed

A daunting task…

Where can we look for help?

Malware is prevalent

- Trojans
- Viruses
- Worms
- Spyware
- DLL injection
- Bots
- Rootkits
- Hijacking
- Keystroke logging
- Backdoors
- Hooks
- Malware

Cheats and malware

- What do cheats and malware have in common?
- Software mechanisms used to cheat
  - Binary modifications
  - DLL injection and user-mode hooks
    - Import Address Table (IAT) hooks
      - e.g. DirectX hooks
    - Inline function hooking
  - Code caves
  - Kernel modules and kernel-mode hooks
    - See-through graphics drivers
    - Layered drivers
    - I/O, System Service Dispatch Table (SSDT), Interrupt Descriptor Table (IDT), Structured exception handler hooks
    - Packet editing
- An entire course could be devoted to this…
  - http://thefengs.com/wuchang/work/courses/cs592

Cheats and malware

- What else do they have in common?
- Software mechanisms used by counter-measures
  - File system integrity checks
  - Memory scanning
  - Process monitoring
  - Remote measurement (e.g. PunkBuster screenshots)

  - Examples
    - Tripwire, Symantec, chkrootkit, Snort, etc. (anti-malware)
    - HLGuard, VAC, PunkBuster, Warden (anti-cheat)

Cheats and malware

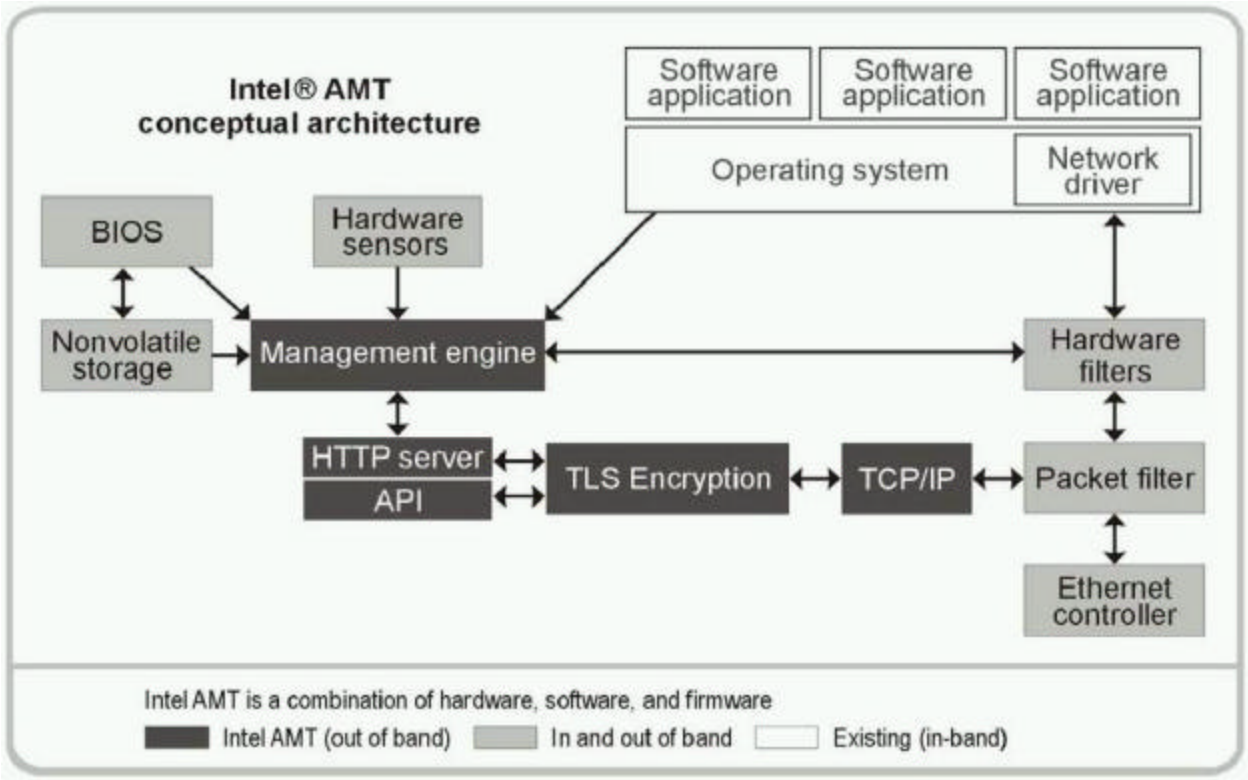
- What else do they have in common?
- Fatal flaws in counter-measures
  - Easily subverted or disabled by adversary
  - Adversary finds a way to run at “Ring 0” via privilege escalation or in-kernel drivers
  - Adversary modifies
    - Operating system
    - Any memory location
    - Drivers
    - Even the anti-cheat system itself!
  - Warden vs. WoW Glider
- Towards a common approach for securing counter-measures
  - Get “beneath” the cheat/malware
  - Rely on an “Angel in the Box”

Angel in the Box

- A trusted, tamper-resistant processor that is hidden from the applications and operating system running on the host
  - Ring “–1”
  - Only runs signed code
  - Has access to key components of running system
- Paradigm
  - Run any cheat you want, but the angel is watching

Example Angel

- Intel's Active Management Technology platform



Using the Angel

- Currently being used to secure hosts
  - Tamper-proof detection of rootkits, spyware, viruses, and malware via memory and file system integrity checks
  - Tamper-proof monitoring of critical processes
  - Network quarantine
- Applied to games
  - Tamper-proof detection of cheats via memory and file system integrity checks
  - Tamper-proof monitoring of anti-cheats and peripherals
  - Game protocol integrity

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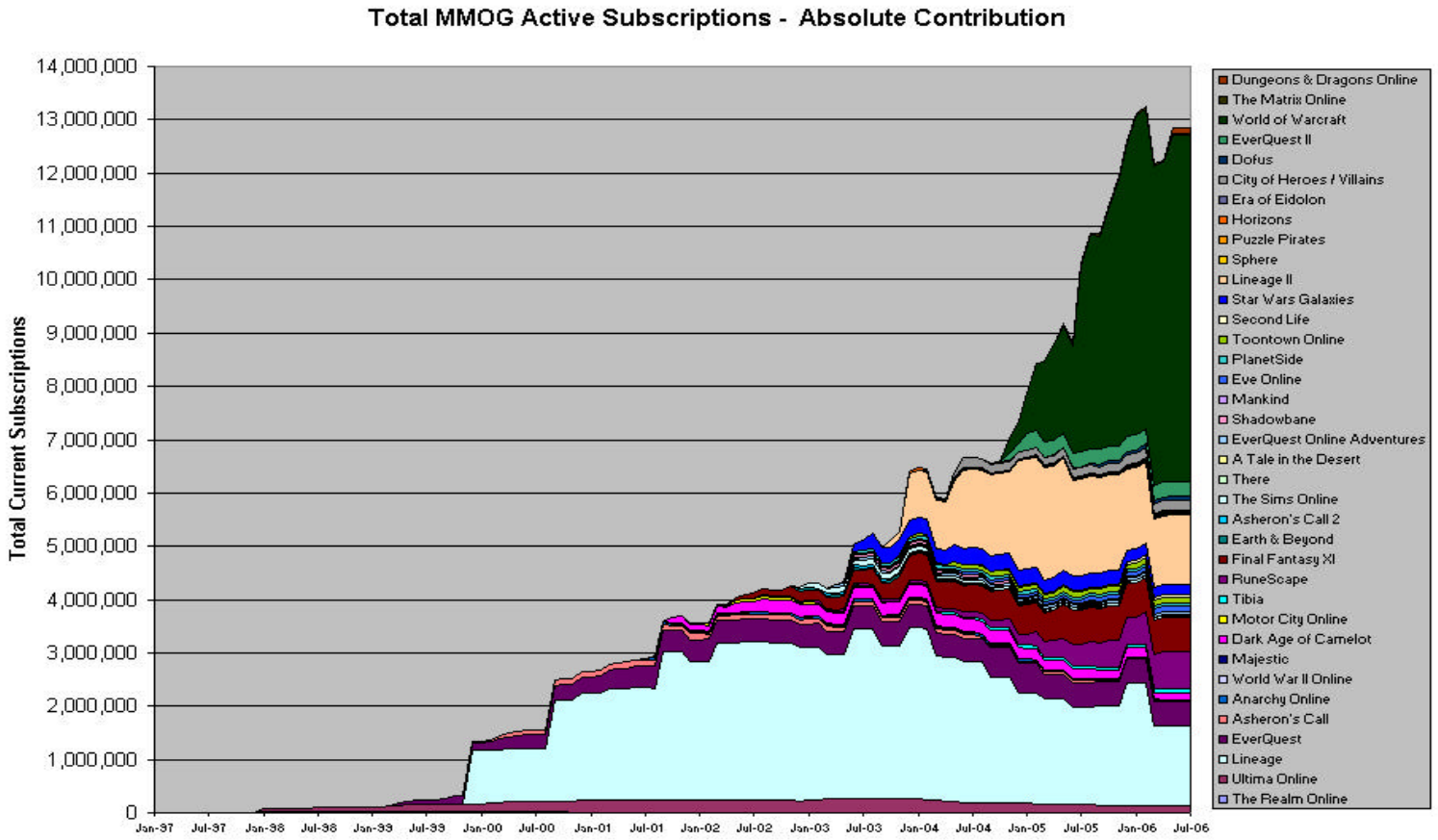
MMORPG

- Massively Multiplayer Online Role-Playing Game
  - One of the most popular game genres
  - Popular MMOs
    - World of Warcraft, Lineage



MMORPG problems

- Centralized hosting expensive
  - Hosting costs: 20% of subscription revenue
  - Support costs: 20% of subscription revenue
- Content generation expensive
  - Dominate cost of MMOs after launch
  - Costs growing faster than game revenue
- What are games without those problems?

Public server games

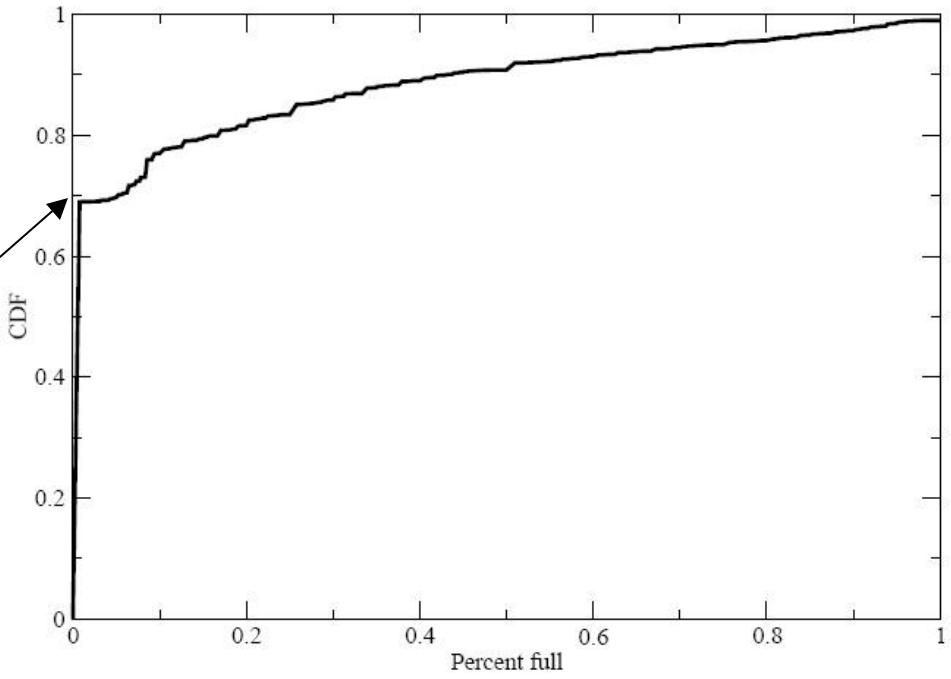
- What’s a public server game?
  - Game company distributes the server code
  - Users run the code on their own servers (available publicly)
  - Users can modify the server
  - Examples
    - Half-life, Counter-Strike, Neverwinter Nights
- Drawbacks
  - No subscription model
  - Not “massive”
  - No persistent world
- Benefits
  - Leverage user hosting and content generation resources

User resources

- How much is there much to harness?
  - Server resources
  - Content generation resources

Server resources are plentiful

70% of all servers are empty



CDF of fullness of Counter-Strike servers

User content generation plentiful

- Half-life
  - 6 official mods
  - 492 user-developed mods (on Wikipedia alone)
    - Counter-Strike originally a user mod
- Neverwinter Nights
  - 7 studio-developed modules (expansions)
  - 4372 user-developed modules
- Second Life
  - 80k player-hours / day spent playing
  - 25% is user content creation!
  - 10 user-years/day in content development
- User content as popular or more popular than studio content

Our Goal: Public Server MMORPG

- Decrease hosting and support costs by letting users host gameplay
- Decrease development costs by letting users generate content
- Allow for a persistent world built with public servers

Categorizing existing games

	User content	Architecture	Persistent
Typical RTS		**P2P**	
Typical MMO		**Client-server**	**X**
Typical FPS	**X**	**Public server**	
Neverwinter Nights	**X**	**Public server**	
Second Life	**X**	**Client-server**	**X**
PS MMO	**X**	**Public server**	**X**

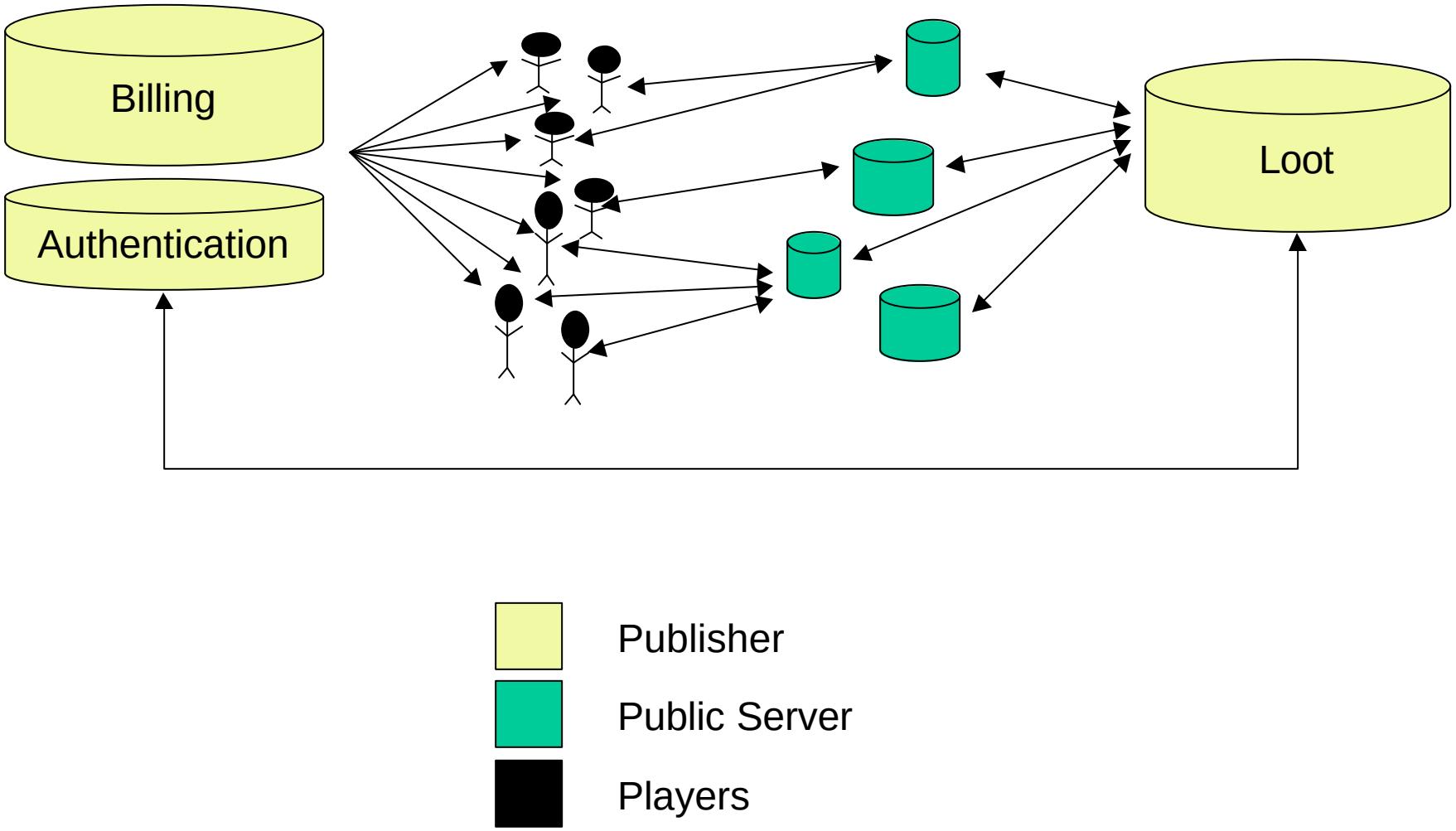
Incentive-based design

- Player incentives unchanged
  - Fun
  - Persistent loot/advancement for time invested
- Hosting and content generation incentives
  - Pride
    - e.g. Second Life
  - Control of game rules and maps
    - e.g. Half-Life, Counter-Strike
  - Control of loot
    - Public servers awarded loot (virtual and real) based on player-minutes
    - Player-minutes drive PSMMO's virtual economy
    - Public servers must provide compelling content to keep players on their server

PSMMO Overview

- Public servers host gameplay
- Publisher hosts authentication, billing, loot server
- Players store persistent data (i.e. loot) themselves
- Key challenges
  - Network all those servers together (we don’t do this)
  - Provide great uptime with user-run servers (or this)
  - Authentication
  - Issuing, verifying, managing the persistent data

PSMMO architecture

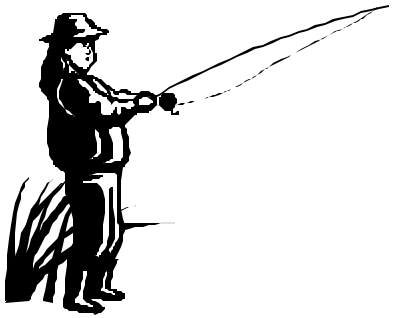


Example: CSMMO

- Imagine Counter-Strike the MMO
- Player picks a public server to play on from many
- Player advances a persistent state via gameplay tasks
  - Earns tokens via kills and victories
  - Trades tokens in eventually for better (persistent) loot
- Loot examples
  - Better weapons
  - Faster running speed
  - New outfits
  - Trophy rack
  - Bank account

Why focus on loot?

- Loot is very important
  - Primary motivator for gameplay in MMOs
  - Loot is the persistent reward
  - Acquiring abilities, possessions, statistics, money can cost players hundreds of hours
- Keeps gameplay open to publisher/user innovation
  - Public servers decide game rules/content and how to issue loot
  - Can vary from public server to public server
  - CS, fishing, chess, driving, killing monsters
  - Competitive vs. cooperative games



Design pitfalls (incomplete)

- Anyone can put up a server!
  - Can they play on their own server and win all the time?
  - What do they get?
  - Can they write a bot to play on their own server, away from prying eyes?
- Anyone can design loot!
  - Can they design the most powerful loot?
  - Can they issue it to themselves?
- Anyone can join a server, and clients store their own data!
  - How can a server trust a client’s loot?

Design goals to address cheating

- Ensuring player-minutes are not fabricated and are not being played by bots
- Ensuring loot is not fabricated or duplicated
- Ensuring loot is balanced and fair

Ensuring player-minutes are authentic

- Players periodically authenticated by authentication server to determine which public server is accumulating their player-minutes
- Players periodically tested with CAPTCHAs by the authentication server
- Each completion of a CAPTCHA grants authenticated player minutes to that player's server
- Prefer game-specific tests to avoid generic CAPTCHA farms

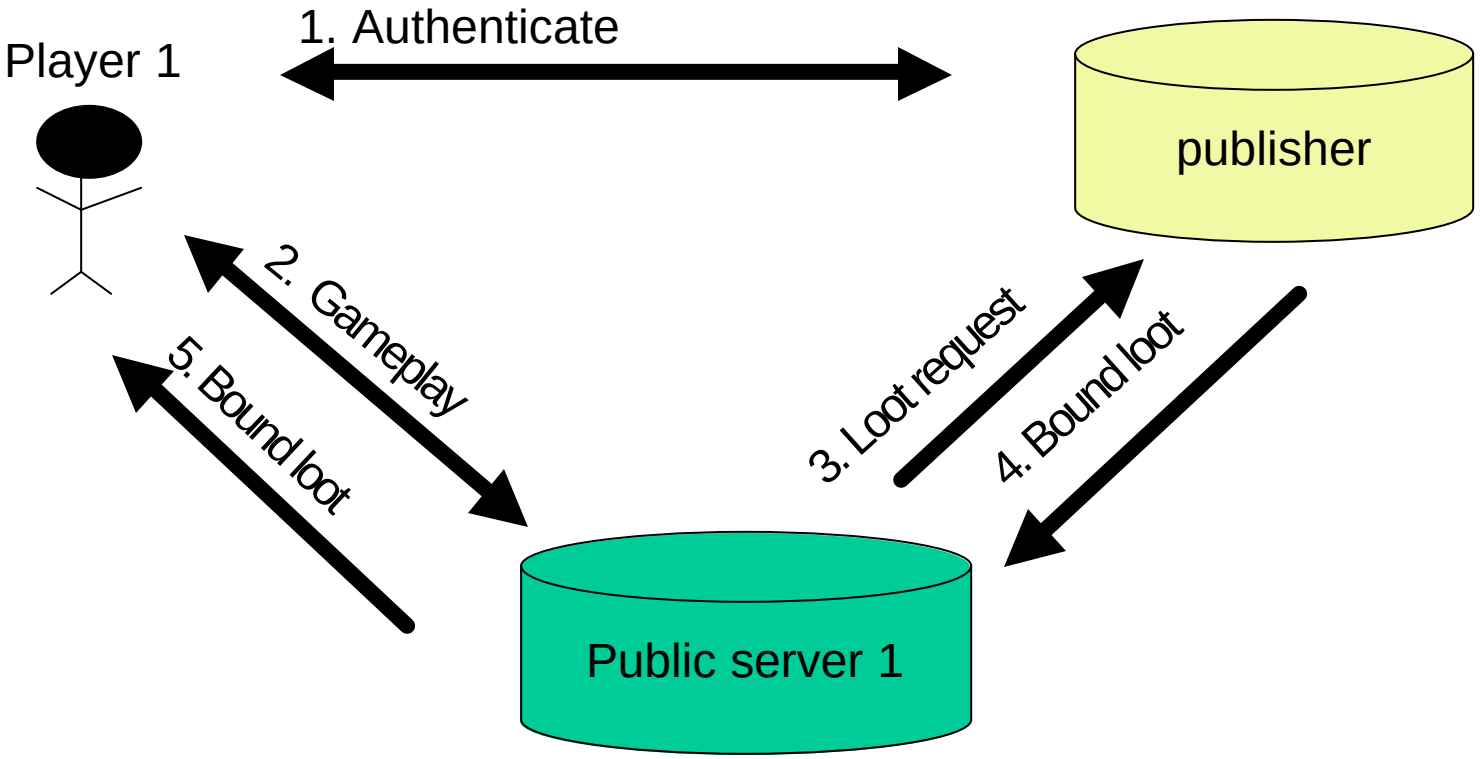
Ensuring loot is authentic

- Loot issued to servers based on authenticated player minutes logged at the server
- Loot “minted” via a centralized loot server using public-key cryptography
  - Loot server creates loot and binds it to player
  - Loot server uses its private key to sign loot
  - Public servers ensure loot is authentic using loot server’s public key

Ensuring loot is balanced

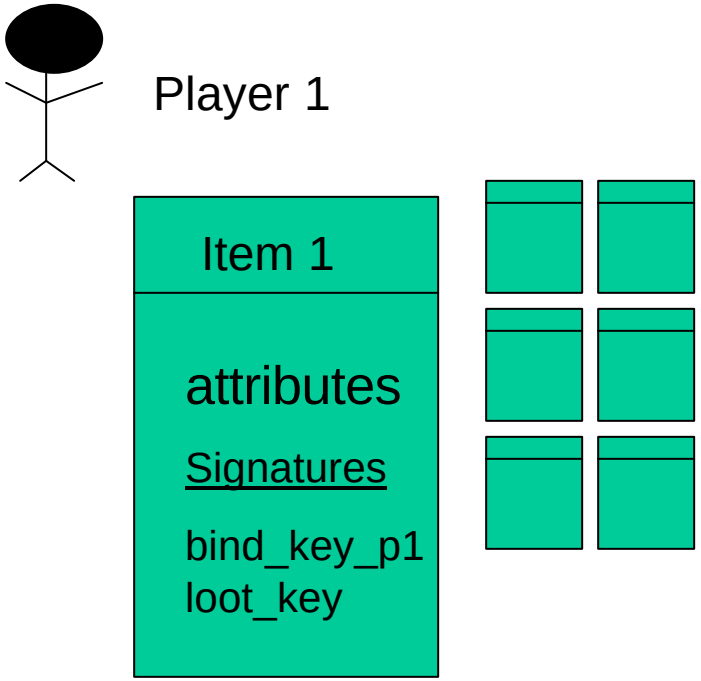
- Users design any sort of gameplay
- Users design any non-persistent loot for their mod
- Users design persistent loot, but such loot must be examined and balanced by publisher before being issued by loot server
  - Persistent loot must meet verifiable standards (e.g., point balanced)
  - Publisher examines and rates the power of user generated loot before allowing loot server to issue
  - Loot server ensures power of issued loot is proportional to player-minutes

Overall operation



Limitations (incomplete list)

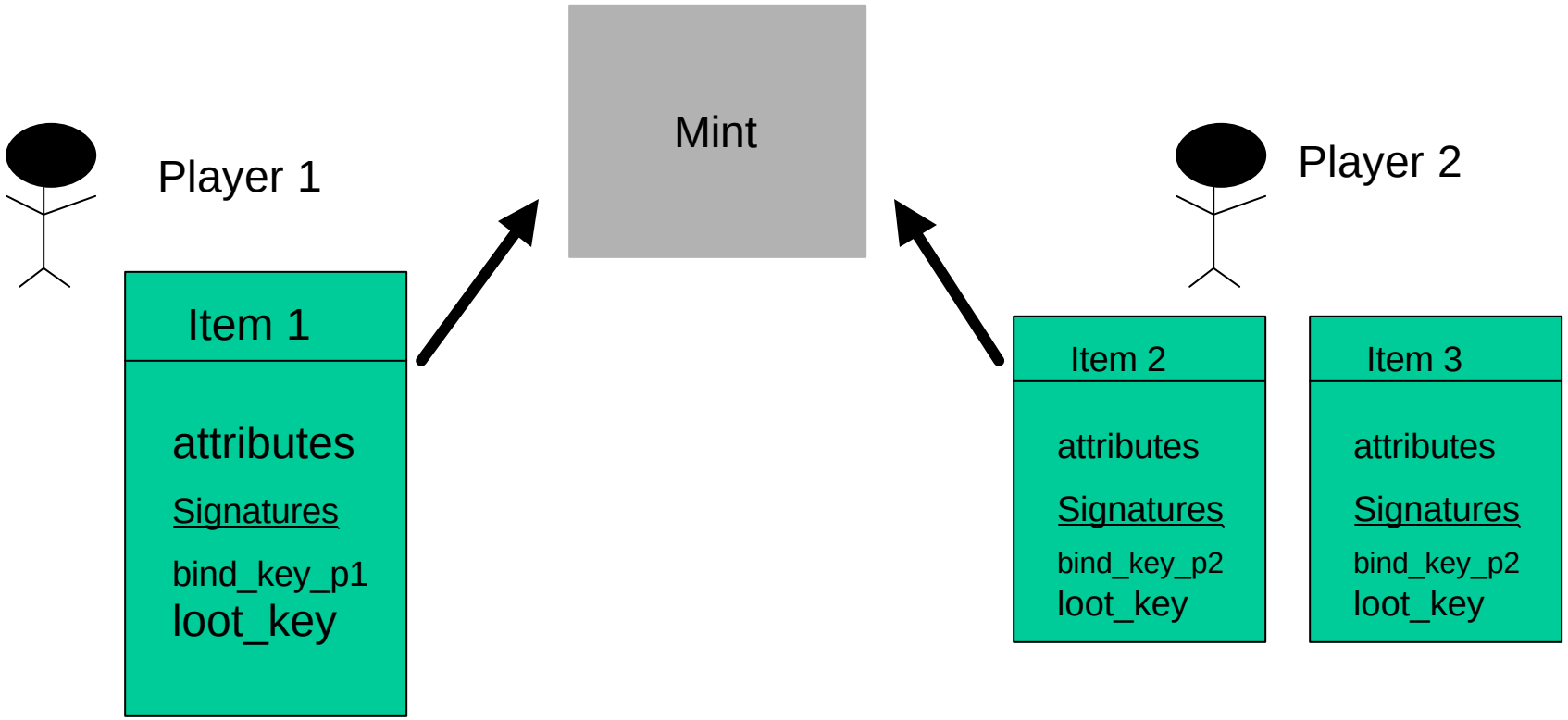
- Player stores loot
  - Has to manage backups
  - Has to manage across computers
- Loot is bound to a player
  - No trading with other player
  - No buying or selling



Challenge: Trading Items

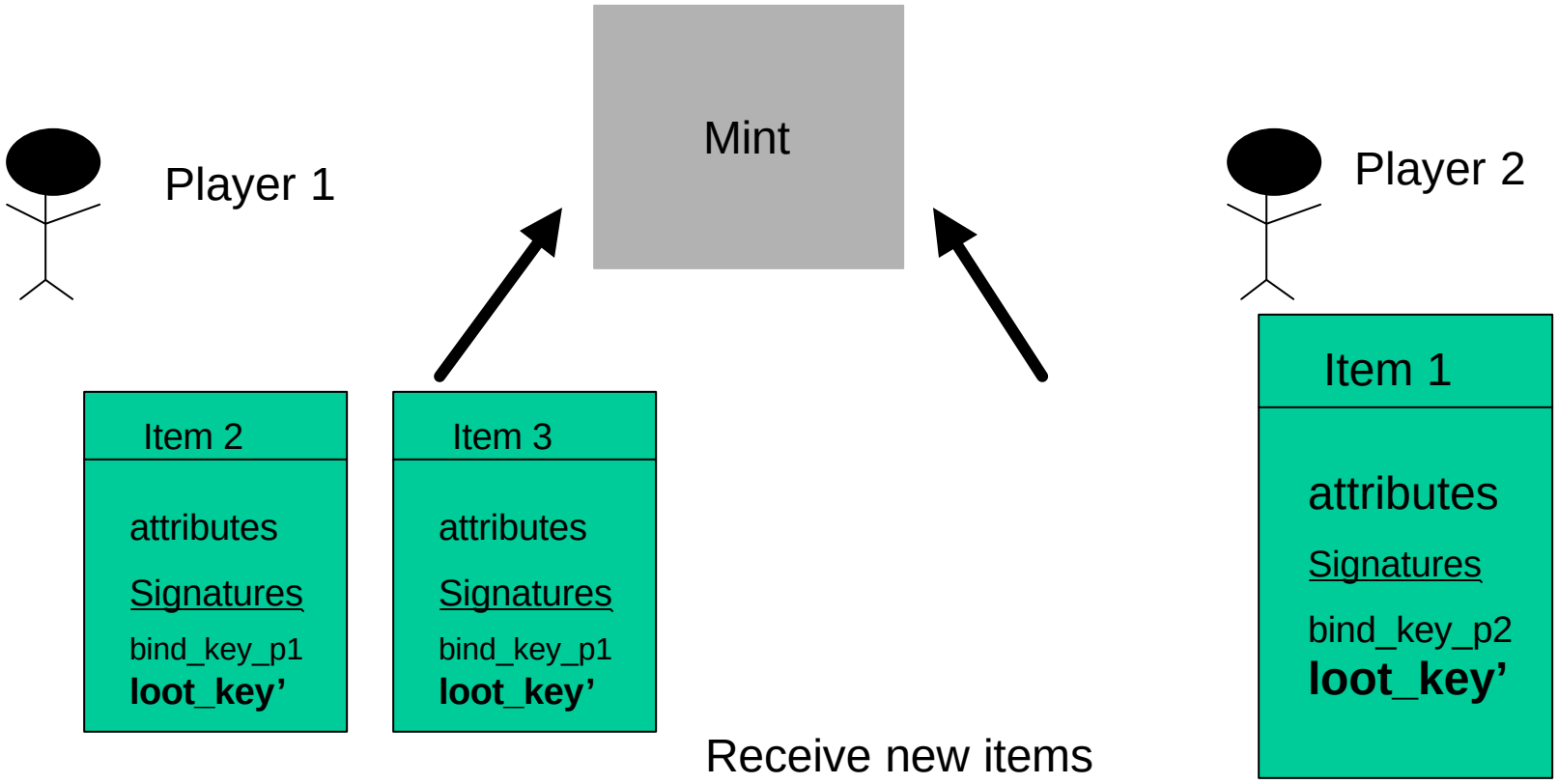
- We would like to relax the “loot cannot be traded” restriction for game-play purposes
- Trade: Player A had item, now Player B does
  - How can player A not have it anymore?
  - We don’t want to allow item duping
  - We don’t want to keep an item revocation list (not scalable)
- Solution: periodic trading window and item re-minting
  - Publisher coordinates a player-wide swap meet or auction
  - During auction, all items of players on-line are re-minted
  - Old items are invalidated by changing minting keys (*Loot_key_pub*, *Loot_key_priv)*
  - Loot server re-mints items based on trades using new minting keys
  - Off-line players have their items re-minted using new minting keys upon next connection

Trading Illustration



Submit items to mint

Trading Illustration



Burning questions

- How can we prevent servers from giving players loot for doing nothing?
  - We don’t
  - We do require players to be actively playing and we assume they will gravitate towards compelling content
- How can we prevent servers from running unfair gameplay rules (eg, only give loot to admin)
  - We don’t
  - In other public server games, players avoid cheating servers by reputation
  - Servers taking a cut of the loot may actually be okay with players!

Summary

- Public-server architecture for persistent MMORPG
- Key incentive
  - Public servers earn loot for authenticated player-minutes
- Advantages
  - Leverage user resources in content generation and hosting
- Disadvantages
  - Limited trading, no guarantees of fair gameplay

C. Chambers, W. Feng, W. Feng, “Towards Public Server MMOs”, NetGames 2006.

Conclusions

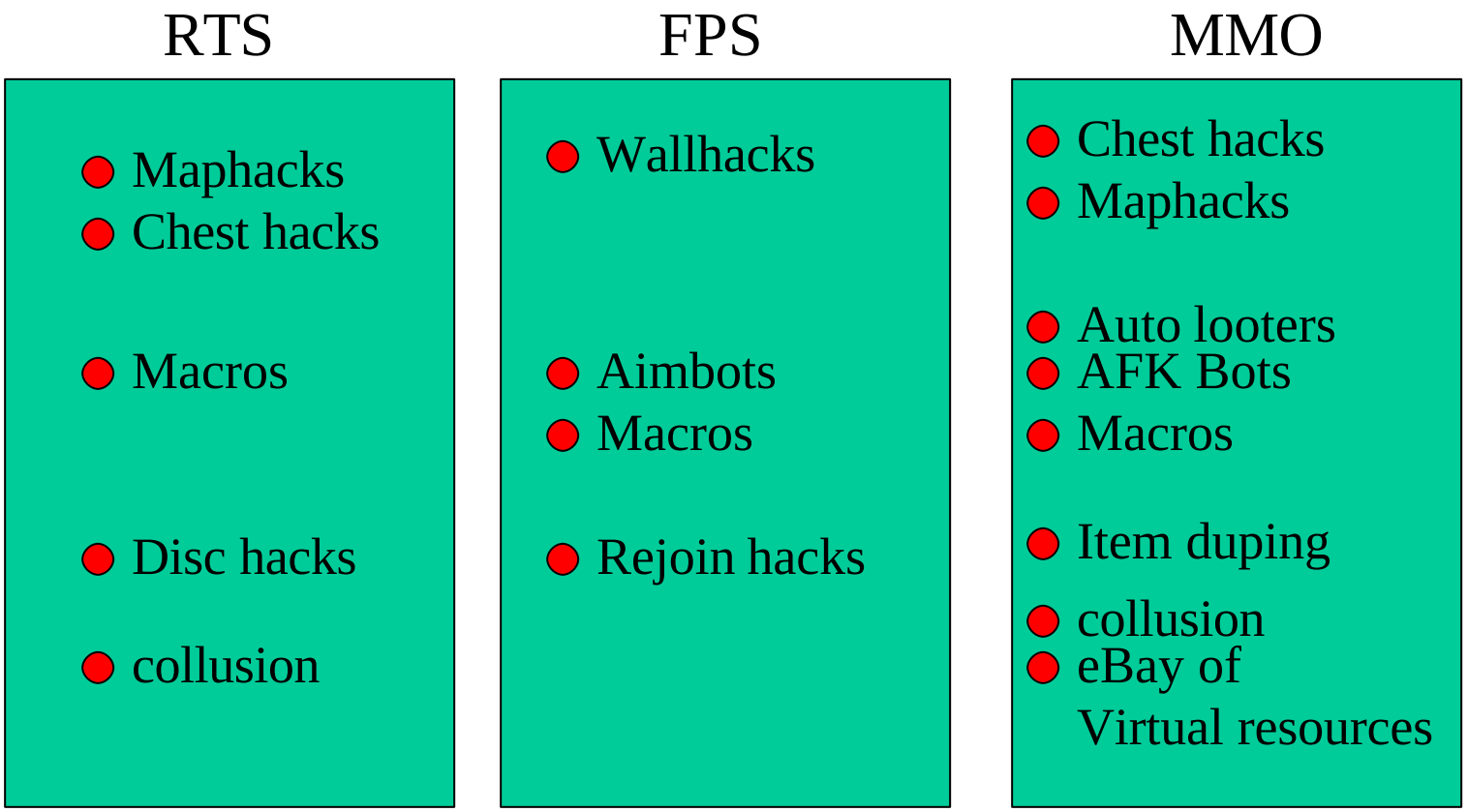
- Cross-pollination of security and games can be profitable
  - Protects existing on-line games
  - Creates new game architectures with better cost structures

http://thefengs.com/wuchang/work/cstrike

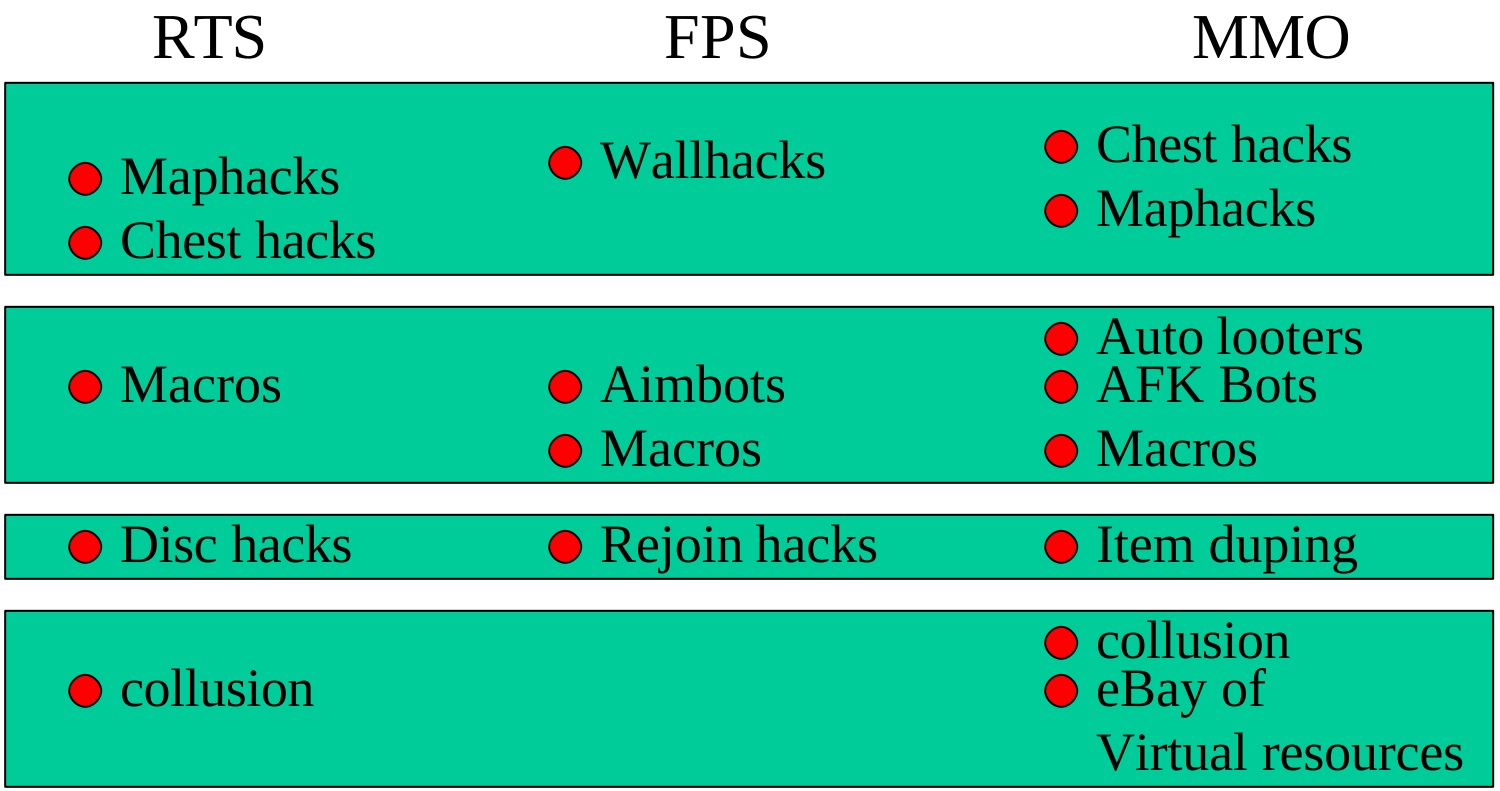
http://mshmro.com

Extra slides

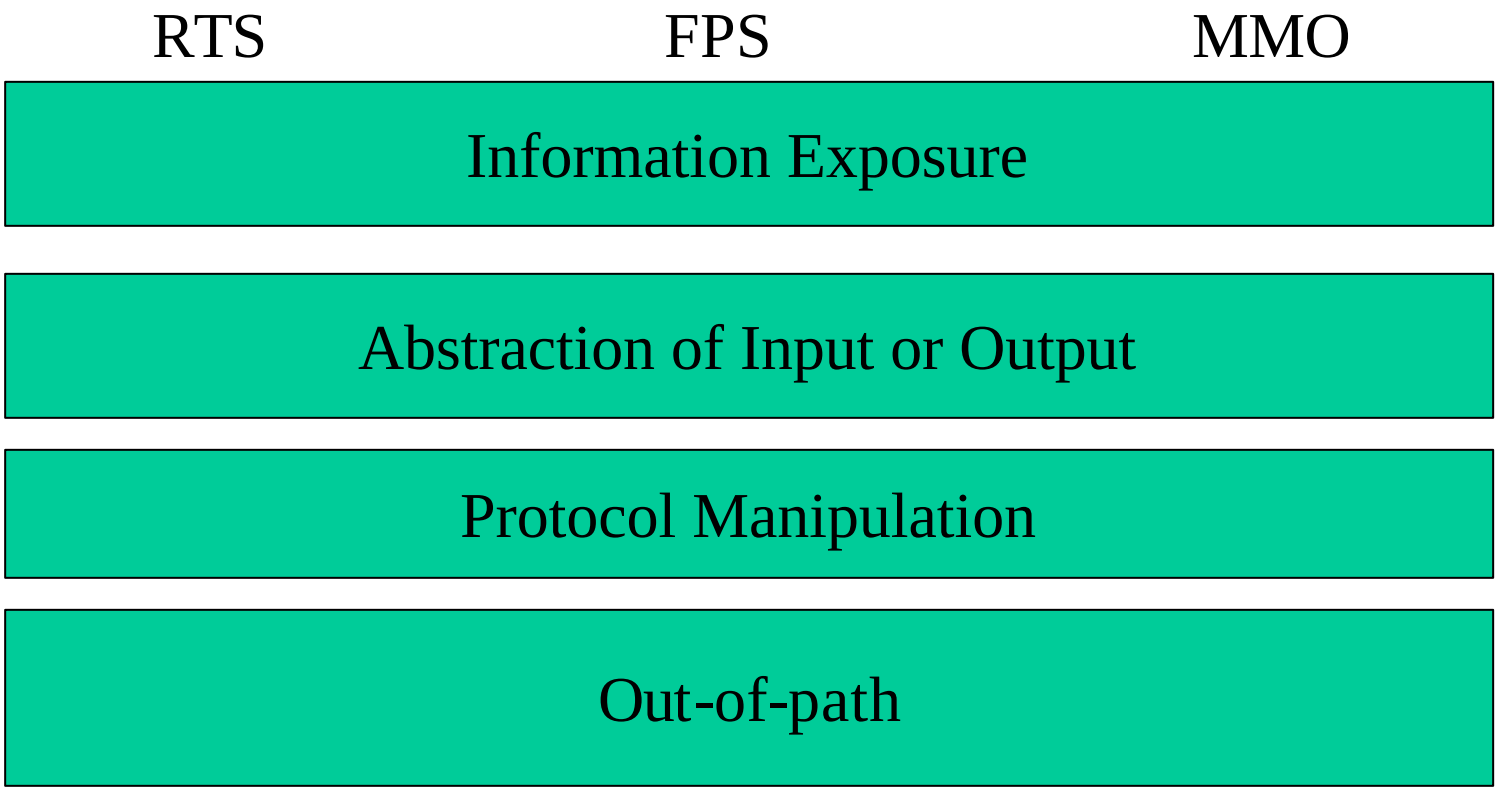
Cheating is prevalent across genres



Categorize cheats to address them



Categories of cheats

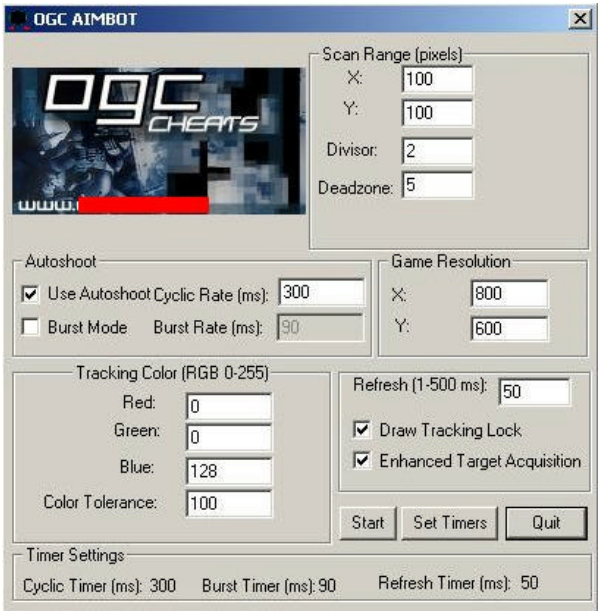


Examples of cheats per category

- Information exposure
  - Wallhacks (OGC), Maphacks (Warcraft 3), Chest hacks (showEQ)
- Automation and abstraction
  - Aimbot (OGC), Troop command macros (Warcraft 3), Auto-looting (WoW QuickLoot), AFK bots
- Protocol
  - Reset cheat (Half-Life), Unit fabrication (Warcraft 3), Item duping (MMO), Speed hack (Half-Life), Hit point hack (Diablo), Disconnect cheat
- Game bugs
  - Game-specific coding errors that lead to unintended behavior

Automation cheats

- Automate game activities via Bots
- Aimbots
  - OGC
  - Automate aiming in FPS
- Macros and game bot farming
  - MacroQuest for EQ2
  - Automate wealth acquisition via programs



Abstraction

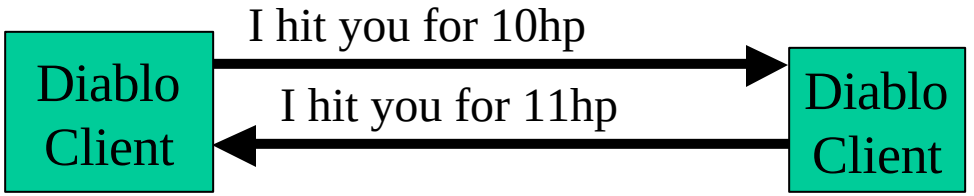
- Input Abstraction, Output Abstraction
- AI Definition: *write user inputs or gameplay messages decreasing user interactivity*
- AO Definition: *display refined information to the user to guide input*
- Examples:
  - FPS: Aimbots (AI)
  - RTS: Troop command macros (AI)
  - MMO: bots for selling buffs (AI)
  - Cards: card counting (AO)
  - FPS: color enemies red (AO)

Protocol cheats

- Hit point cheating
  - Diablo protocol messages indicating damage done to enemy
  - Inject messages with inflated damage to instantly kill opponent
- Item duping
  - Disconnect while dropping item
  - Ambiguity in whether event happened globally
- Speed hack
  - Inject movement messages to make your character move or fire “faster” than normal

Protocol Cheats

- Definition: *write messages not generable by user actions to exploit weaknesses in communication protocol*
- The Problem: server API suffers bugs and design flaws/tradeoffs like any other code
- Protocol cheats take advantage of squiggle room in protocol
- Examples:
  - FPS: player reset
  - RTS: inventing units
  - MMO: item duping
  - Speedhacks



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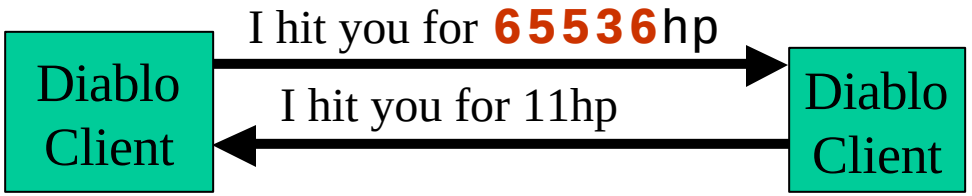

Game cheats

- Exploit inconsistencies and errors in game code
  - Magic “pizza” machine in The Sims On-line
  - Vending machine and pawn shop hack in Lucasfilm’s Habitat
  - Skin cheats in Counter-Strike
  - Not highly relevant to this course

Out-of-path cheats

- Important problems, not in the control path
- Rule: “If it can be achieved via normal gameplay, it’s not a control path cheat”
- Things not considered control path cheats that are still bad include…
  - Game bugs such as duping via normal gameplay
  - Map exploits
  - Vendor design exploits
- More Examples:
  - Password stealing, cd-key stealing, DDOS, remote root
  - Buying/selling virtual items on eBay
  - Collusion, two-boxing
  - Performance-enhancing drugs, robots

Bit commitment example

- Fair coin flip
  - Each participant comes up with a secret key
  - Selects and encrypts either “heads” or “tails”
  - Exchanges encrypted messages
  - Exchange secret keys
  - Whoever was the “flipper” wins if answers differ, loses if they’re the same

Cheating links

- General
  - http://rpgexploits.com
  - http://msxsecurity.com
  - http://zerogamers.com
- WoW
  - WoW Glider
    - http://wowglider.com
  - WoW radar, WoW Sharp, ByteBot, GALB
  - WardenNet, ISXWarden (anti-anti-cheats)
    - http://ismods.com/warden
    - http://edgeofnowhere.cc/viewtopic.php?t=311208
    - http://www.rootkit.com/newsread.php?newsid==360
  - ISXWoW
    - http://ismods.com/downloads.php

Cheating links

- Half-Life
  - OGC
    - http://mpcdownloads.com
    - http://www.mpcforum.com/showthread.php?t=31409
- EverQuest 2
  - MacroQuest
    - http://sourceforge.net/projects/macroquest

Anti-cheat links

- WoW Warden
  - http://www.ismods.com/warden
- PunkBuster
  - http://punkbuster.com
- Valve Anti-Cheat (VAC)
  - http://server.counter-strike.net/server.php?cmd=VAC
- HLGuard, Cheating-Death
  - http://unitedadmins.com
- Intel's AMT
  - http://www.intel.com/go/iamt/