RFC-001: R-Type Game Protocol (RTGP)

Metadata	Details
Version	1.4.1 (Entity Move Batching + Lobby System)
Status	Draft / Experimental
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Abstract	This document specifies the binary application-layer protocol used for real-time communication between the R-Type Client and Server, including a reliability layer over UDP.

1. Introduction

The R-Type Game Protocol (RTGP) is a lightweight, binary, datagram-oriented protocol designed to facilitate real-time multiplayer gameplay. It prioritizes low latency and bandwidth efficiency while providing a selective reliability mechanism (RUDP) to ensure critical game events are delivered.

2. Terminology & Conventions

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119.

2.1. Data Types

- **Byte:** 8-bit unsigned integer.

- **uint16:** 16-bit unsigned integer.
- **uint32:** 32-bit unsigned integer.
- **int32:** 32-bit signed integer.
- **float:** 32-bit IEEE 754 floating point.
- **String:** NOT SUPPORTED in standard packets to avoid allocation overhead, unless specified in the payload.

DisconnectReason Enum

The `DisconnectReason` is a uint8 value indicating why a connection was terminated:

Value	Name	Description
0	Timeout	Connection timed out due to lack of response
1	MaxRetriesExceeded	Maximum retry attempts exceeded
2	ProtocolError	Protocol violation or invalid packet
3	RemoteRequest	Disconnect requested by remote peer
4	LocalRequest	Disconnect requested locally

2.2. Byte Order

All multi-byte numeric fields **MUST** be transmitted in **Network Byte Order (Big-Endian)**. Implementations on Little-Endian architectures (x86/x64) MUST convert data before transmission (htons, htonl) and after reception (ntohs, ntohl).

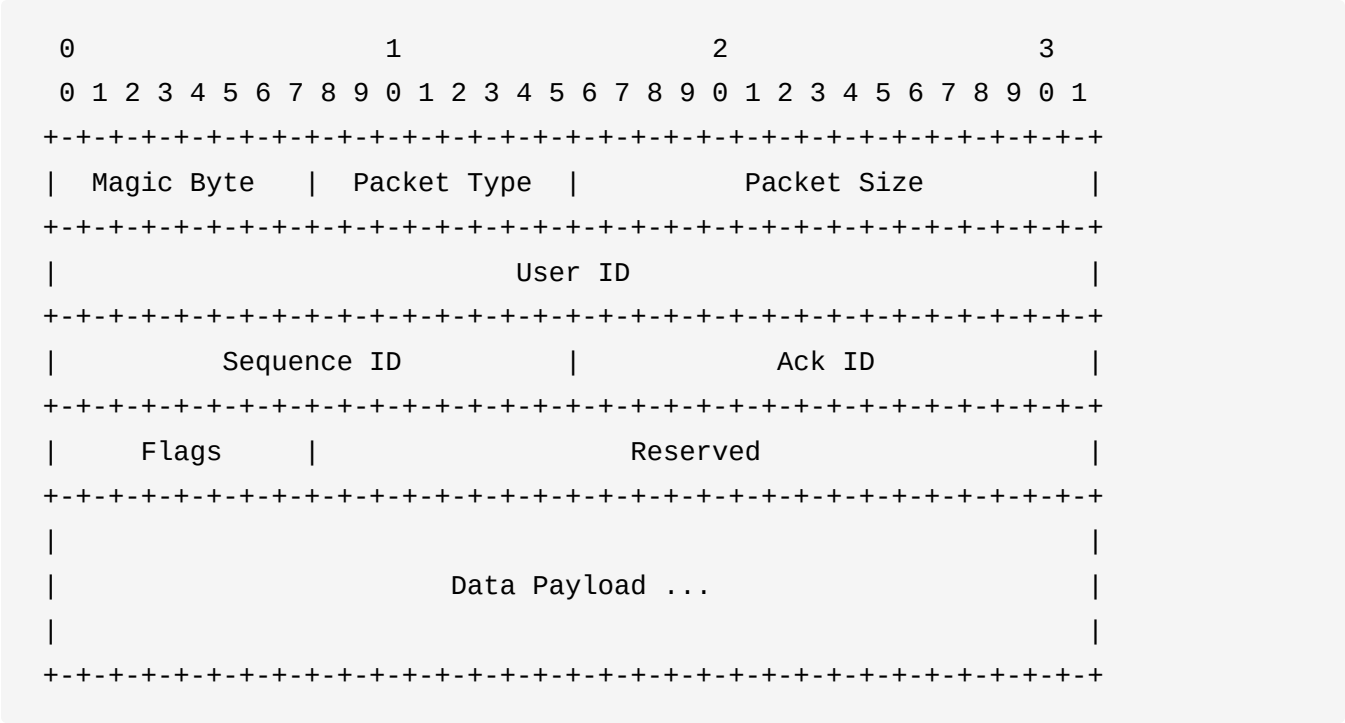
3. Transport Layer

- **Protocol:** UDP (User Datagram Protocol).
- **Default Port:** 4242.
- **MTU Safety:** The total packet size (Header + Payload) **SHOULD NOT** exceed 1400 bytes to avoid IP fragmentation on standard networks.

4. Packet Structure

Every RTGP packet consists of a fixed **16-byte Header** followed by a variable-length **Data Payload**.

4.1. Header Format



Field Definitions:

Field	Type	Description
Magic Byte	uint8	**MUST** be 0xA1. Used to filter spurious traffic.
Packet Type	uint8	The Operation Code (OpCode) defined in Section 5.
Packet Size	uint16	Length of the **Data Payload** in bytes. Excludes Header size.
User ID	uint32	The sender's unique identifier.
Sequence ID	uint16	Incremental ID of the packet sent. Wraps at 65535.
Ack ID	uint16	The Sequence ID of the last packet successfully received.
Flags	uint8	Bitmask for packet attributes (see 4.3).

Field	Type	Description
Reserved	3 bytes	Padding for 16-byte alignment. MUST be 0.

4.2. User ID Conventions

- **Server Authority:** 0xFFFFFFFF (-1). Only the Server uses this.
- **Unassigned Client:** 0x00000000. Used during handshake.
- **Assigned Client:** 0x00000001 to 0xFFFFFFFE.

4.3. Reliability Mechanism (Flags)

The `Flags` field is used to manage the reliability layer (RUDP) and compression.

Flag Bitmask Values:

- **0x01 - RELIABLE:** The sender requests an acknowledgement for this packet. The receiver **MUST** acknowledge this packet (either via a dedicated ACK or piggybacking).
- **0x02 - IS_ACK:** The `Ack ID` field in this header is valid and acknowledges a previously received packet.
- **0x04 - COMPRESSED:** The payload is compressed using LZ4 frame format. The receiver **MUST** decompress the payload before processing.

Behavior:

1. **Sequence ID:** MUST be incremented by 1 for every new packet sent.
2. **Ack ID:** MUST always contain the Sequence ID of the last valid packet received from the remote peer.
3. **Retransmission:** If a packet marked `RELIABLE` is not acknowledged within a specific timeout (e.g., 200ms), the sender MUST retransmit it.

4.4. Compression

RTGP supports optional LZ4 compression for payloads to reduce bandwidth usage.

Compression Behavior:

1. **Threshold:** Payloads smaller than 64 bytes **SHOULD NOT** be compressed (overhead exceeds benefit).
2. **Format:** LZ4 frame format is used, which includes decompressed size metadata for safe buffer allocation.
3. **Header Field:** `Packet Size` (payloadSize) contains the **COMPRESSED** size, not the original size.
4. **Flag:** When payload is compressed, the COMPRESSED flag (0x04) **MUST** be set.
5. **Backward Compatibility:** Receivers **MUST** support both compressed and uncompressed packets. If COMPRESSED flag is not set, payload is processed as-is.

Decompression Requirements:

1. Receivers **MUST** check the COMPRESSED flag before processing payload.
2. If decompression fails, the packet **MUST** be dropped and **MAY** be logged.
3. Decompressed size **MUST NOT** exceed `kMaxPayloadSize` (1384 bytes).

5. Protocol Operations (OpCodes)

5.1. Session Management

0x01 - C_CONNECT

- **Sender:** Client
- **Reliability: RELIABLE** (Flag 0x01)
- **Description:** Request to establish a connection.
- **Payload:** Empty.

0x02 - S_ACCEPT

- **Sender:** Server
- **Reliability: RELIABLE** (Flag 0x01)
- **Description:** Connection accepted. Assigns the User ID to the client.
- **Payload:**
  - New User ID (uint32)

0x03 - DISCONNECT

- **Sender:** Client OR Server
- **Reliability: RELIABLE** (Flag 0x01)
- **Description:** Graceful termination of the session.
- **Payload:**
  - Reason (uint8): DisconnectReason enum value indicating why the connection is being terminated.

0x04 - C_GET_USERS

- **Sender:** Client
- **Reliability: RELIABLE**
- **Description:** Request a list of currently connected players (Lobby).
- **Payload:** Empty.

0x05 - R_GET_USERS

- **Sender:** Server
- **Reliability: RELIABLE**
- **Description:** Server responds to C_GET_USERS.
- **Payload:**
  - Count (uint8): Number of users.
  - UserIDs (uint32[]): Array of User IDs.

0x06 - S_UPDATE_STATE

- **Sender:** Server
- **Reliability: RELIABLE**
- **Description:** Notifies clients of a global game state change.
- **Payload:**
  - StateID (uint8): 0=Lobby, 1=Running, 2=Paused, 3=GameOver.

0x07 - S_GAME_OVER

- **Sender:** Server
- **Reliability: RELIABLE** (Flag 0x01)
- **Description:** Notifies clients that the game has ended with the final score. This is sent when

the game reaches a terminal state.

- **Payload:**
  - Final Score (uint32): The final accumulated score.

0x08 - C_READY

- **Sender:** Client
- **Reliability: RELIABLE** (Flag 0x01)
- **Description:** Client signals ready/unready state in the lobby. When all players are ready, the server initiates the game start sequence.
- **Payload:**
  - Is Ready (uint8): 1 if ready, 0 if not ready.

0x09 - S_GAME_START

- **Sender:** Server
- **Reliability: RELIABLE** (Flag 0x01)
- **Description:** Server signals that all players are ready and the game is starting. Includes countdown duration for client-side countdown display. Sent when the server determines all required players are ready.
- **Payload:**
  - Countdown Duration (float): Duration in seconds for the countdown timer (e.g., 3.0 for 3 seconds).

0x0A - S_PLAYER_READY_STATE

- **Sender:** Server
- **Reliability: RELIABLE** (Flag 0x01)
- **Description:** Broadcasts the ready/unready state of a specific player to all clients in the lobby. Typically sent by the server in response to a client's **C_READY** message, or when synchronizing lobby state after a client joins.
- **Payload:**
  - Player ID (uint32): Unique identifier of the player whose state changed.
  - Is Ready (uint8): 1 if the player is ready, 0 if not ready.

5.2. Gameplay & Entity Management

0x10 - S_ENTITY_SPAWN

- **Sender:** Server
- **Reliability: RELIABLE** (Critical: Prevents invisible enemies)
- **Description:** Instructs clients to instantiate a new game object.
- **Payload:**
  - Entity ID (uint32)
  - Type (uint8): 0=Player, 1=Bydos, 2=Missile, 3=Pickup, 4=Obstacle.
  - PosX (float)
  - PosY (float)

0x11 - S_ENTITY_MOVE

- **Sender:** Server
- **Reliability: UNRELIABLE** (Flag 0x00)
- **Description:** Regular state update. If lost, the next update fixes it.
- **Payload:**
  - Entity ID (uint32)
  - PosX (float)
  - PosY (float)
  - VelX (float)
  - VelY (float)

0x12 - S_ENTITY_DESTROY

- **Sender:** Server
- **Reliability: RELIABLE**
- **Description:** Instructs clients to remove an entity.
- **Payload:**
  - Entity ID (uint32)

0x13 - S_ENTITY_HEALTH

- **Sender:** Server
- **Reliability: RELIABLE**

- **Description:** Synchronizes entity health state with clients. Sent when an entity takes damage or is healed. Critical for displaying health bars and handling death events.
- **Payload:**
  - Entity ID (uint32) - The network ID of the entity
  - Current Health (int32) - The entity's remaining health points
  - Max Health (int32) - The entity's maximum health capacity

0x14 - S_POWERUP_EVENT

- **Sender:** Server
- **Reliability: RELIABLE** (Flag 0x01)
- **Description:** Notifies all clients that a player has collected a power-up. This allows synchronization of power-up effects across all game clients.
- **Payload:**
  - Player ID (uint32) - The User ID of the player who collected the power-up
  - Power-Up Type (uint8) - The type of power-up collected (implementation-specific enumeration)
  - Duration (float) - Duration in seconds for temporary power-ups (0.0 for permanent)

0x15 - S_ENTITY_MOVE_BATCH

- **Sender:** Server
- **Reliability: UNRELIABLE** (Flag 0x00)
- **Description:** Batched position/velocity updates for multiple entities. More bandwidth-efficient than individual S_ENTITY_MOVE packets, especially when combined with LZ4 compression. Each tick, all dirty entity updates are grouped into a single packet.
- **Payload:**
  - Count (uint8): Number of entities in the batch (1-69)
  - Entries (EntityMovePayload[]): Array of entity updates, each containing:
    - Entity ID (uint32)
    - PosX (float)
    - PosY (float)
    - VelX (float)
    - VelY (float)

Notes:

- Maximum 69 entities per batch due to MTU constraints: (1384 - 1) / 20 = 69
- If more than 69 entities need updating, multiple batch packets are sent
- LZ4 compression is automatically applied when batch size exceeds 64 bytes (4+ entities)
- Estimated bandwidth savings: 50-60% compared to individual S_ENTITY_MOVE packets

5.3. Input & Reconciliation

0x20 - C_INPUT

- **Sender:** Client
- **Reliability: UNRELIABLE** (Sent frequently)
- **Description:** The client sends its current input state.
- **Payload:**
  - Input Mask (uint8):
    - 0x01=UP,
    - 0x02=DOWN,
    - 0x04=LEFT,
    - 0x08=RIGHT,
    - 0x10=SHOOT.

0x21 - S_UPDATE_POS (Reconciliation)

- **Sender:** Server
- **Reliability: UNRELIABLE**
- **Description:** Correction of client position.
- **Payload:**
  - Authoritative X (float)
  - Authoritative Y (float)

5.4. System & Diagnostics

0xF0 - PING

- **Sender:** Client or Server
- **Reliability: UNRELIABLE**
- **Description:** Latency measurement request. The receiver should respond with a PONG.
- **Payload:** Empty (timestamp can be tracked via seqId).

0xF1 - PONG

- **Sender:** Client or Server
- **Reliability: UNRELIABLE**
- **Description:** Latency measurement response. Echoes the seqId from PING via ackId.
- **Payload:** Empty.

6. Security Considerations

1. **Header Validation:** Any packet where Header[0] != 0xA1 **MUST** be silently dropped.
2. **Sequence Validation:** Packets with a `Sequence ID` significantly older than the last received ID SHOULD be discarded to prevent replay attacks and processing old state.
3. **Spoofing Protection:** The Server **MUST** verify User ID against IP/Port.
4. **Authority Check:** Clients **MUST** ignore packets claiming to be 0xFFFFFFFF (Server) if they do not originate from the known Server IP endpoint.

7. Payload Size Reference

OpCode	Payload Size (bytes)	Notes
C_CONNECT	0	Empty
S_ACCEPT	4	uint32
DISCONNECT	0	Empty
C_GET_USERS	0	Empty
R_GET_USERS	Variable	1 + (count * 4)
S_UPDATE_STATE	1	uint8
S_GAME_OVER	4	uint32

OpCode	Payload Size (bytes)	Notes
C_READY	1	uint8
S_GAME_START	4	float
S_PLAYER_READY_STATE	5	uint32 + uint8
S_ENTITY_SPAWN	13	uint32 + uint8 + float + float
S_ENTITY_MOVE	20	uint32 + 4 * float
S_ENTITY_MOVE_BATCH	Variable	1 + (count * 20), max 1381 bytes
S_ENTITY_DESTROY	4	uint32
S_ENTITY_HEALTH	12	uint32 + int32 + int32
S_POWERUP_EVENT	9	uint32 + uint8 + float
C_INPUT	1	uint8
S_UPDATE_POS	8	2 * float
PING	0	Empty
PONG	0	Empty

8. Changes from Previous Versions

Version 1.4.1 (2026-01-05)

- **Added OpCode 0x15 - S_ENTITY_MOVE_BATCH:** Batched entity position/velocity updates for bandwidth optimization
- **Optimization:** Entity updates are now grouped into a single packet per tick, enabling LZ4 compression
- **Estimated bandwidth savings:** 50-60% for entity movement traffic
- **Added OpCode 0x08 - C_READY:** Client lobby ready/unready signal
- **Added OpCode 0x09 - S_GAME_START:** Server-initiated game start with countdown
- **Added OpCode 0x0A - S_PLAYER_READY_STATE:** Broadcast player ready state changes

- **Lobby Workflow:** Clients send C_READY when toggling ready state. Server broadcasts S_GAME_START when all players ready

Version 1.3.0 (2025-12-15)

- **Added OpCode 0x07 - S_GAME_OVER:** Server notification for game termination with final score
- **Added OpCode 0x14 - S_POWERUP_EVENT:** Synchronization of power-up collection events
- **Added OpCode 0xF0 - PING:** Latency measurement request (previously reserved)
- **Added OpCode 0xF1 - PONG:** Latency measurement response (previously reserved)
- **Updated Section 5.2:** Extended entity type enumeration to include Pickup (3) and Obstacle (4)
- **Added Section 7:** Payload size reference table for quick lookup
- **Updated Section 2.1:** Added int32 data type specification for signed integers

Version 1.2.0 (2025-12-10)

- **Added OpCode 0x13 - S_ENTITY_HEALTH:** Health synchronization for entities

Version 1.0.0 (Initial)

- Initial protocol specification

9. Future Extensions

- **Packet Fragmentation:** Not currently supported. Payloads exceeding MTU must be handled at the application logic level or split into multiple entities.
- **Encryption Layer:** Consider TLS-over-UDP (DTLS) for secure communications.
- **Voice Chat Integration:** Reserved OpCode range 0x30-0x3F for future audio streaming.
- **Replay System:** Reserved OpCode range 0x40-0x4F for game state recording/playback.