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Introduction to Sync Host

Outline

- Motivation
  - Challenges
  - Solution
- Architecture
  - Objects
  - Authority
- Synchronizing Changes
  - Updates
  - Events and Responses
  - Client API

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Challenges

- Singular authority
  - Authority refers to client that is in charge of state changes on an object
    - If multiple clients try to change state on the same object, they will eventually be in inconsistent states
    - Two players try to take a dropped weapon, at the same time and both end up getting it
  - Multiple clients can request changes to state, but only one client can actually make those changes
    - Multiple players can damage a car, but only one player will change its health

Challenges (continued)

- Choosing an Authority
  - How to get clients to agree on who is to be authority of an object
  - Detect that we need to choose a new authority because
    - Authority not yet chosen
    - Current authority is unresponsive (lag, unclean disconnect)
    - Current authority has disconnected
  - Having clients negotiate amongst themselves is time-consuming and often unreliable

Challenges (continued)

- Late-Join
  - Client is joining a game in-progress and needs to have their state brought up-to-date
  - Who sends updates incoming client; basically, who has the authoritative game state
  - Choosing one client has problems
    - Bandwidth strain on chosen client
    - What if the chosen client lags out?

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Solution

- Server to Make Decisions
  - Client always has connection to server – if client looses server connection, then the client gets kicked out of the gam
  - Chooses the authority of objects
  - Has the authoritative (most up-to-date) game state
    - Late-joining clients can ask server for game state update

Solution (continued)

- Differences from a Traditional Server
  - Does not run game-specific logic
  - Maintains a list of clients to pick authority from
  - Database of objects, but does not know what those objects are
    - Each object is just a collection of data
    - Changes to an object's data are routed through the server first so it has authoritative game state
    - Data changes are then forwarded to clients – up to the client to make sense of data changes
  - Data changes are done through messages

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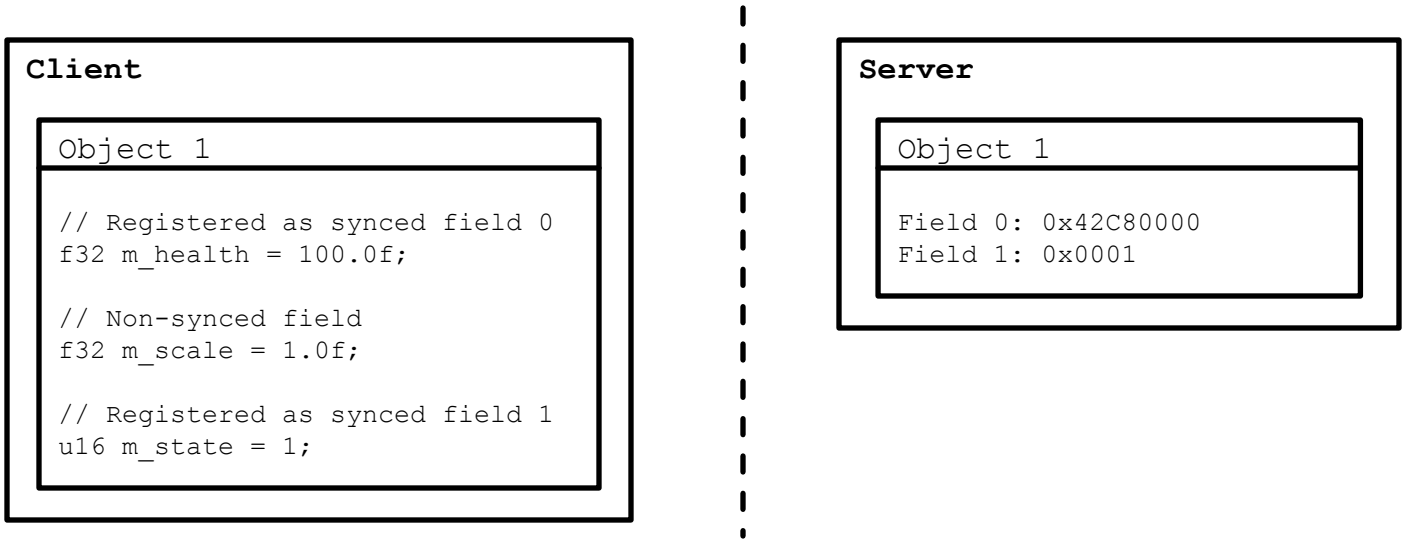
Objects

- Client vs. Server Representation
  - Client has familiar view of object (e.g. an update class)
  - Subset of object data is synced – these are called synced fields
    - Each field of an object has its own id
    - Not all fields need to be synced – only things that when changed, other clients need to know about (position, health)
  - Server only knows about synced fields

Objects (continued)

- Client vs. Server Representation

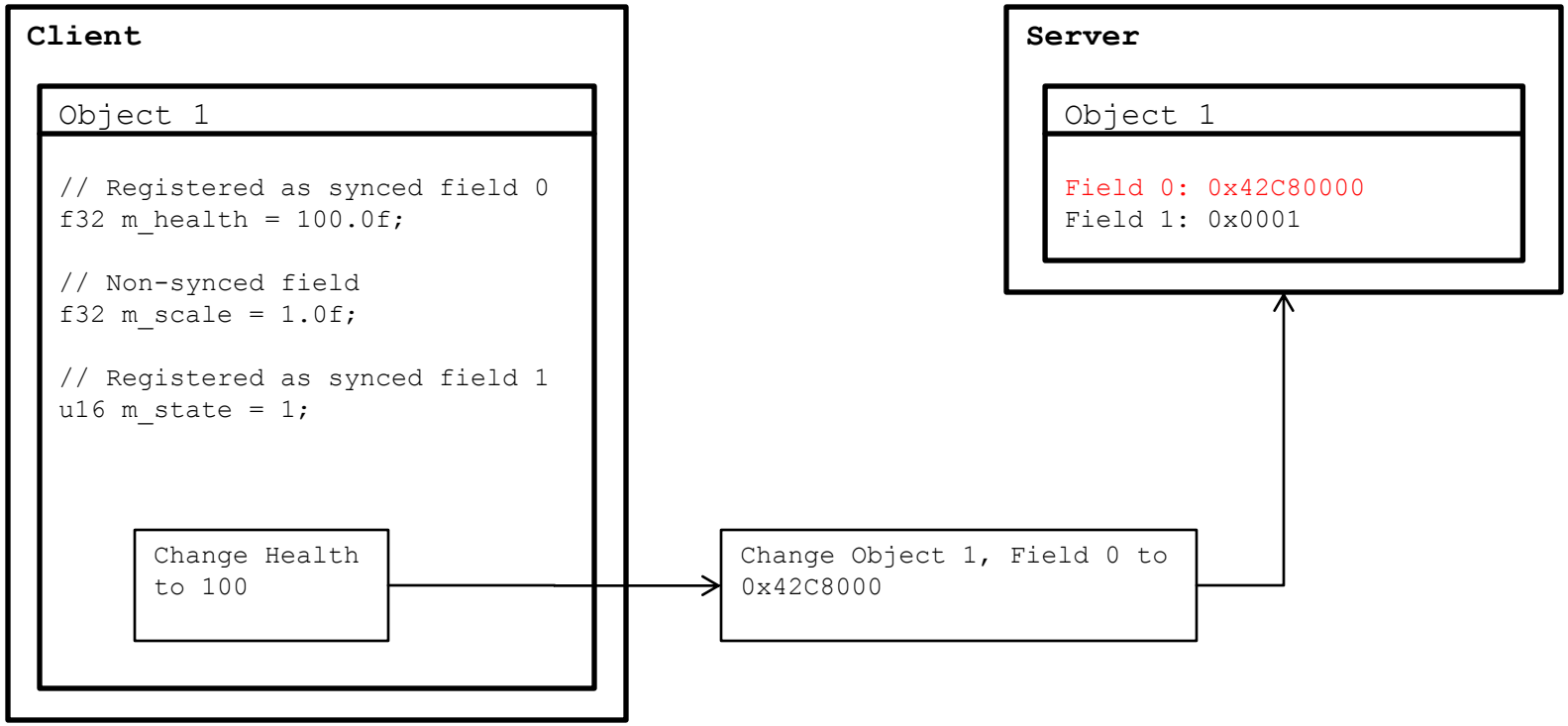


Objects (continued)

- Each object is referenced by a unique object id that is known to the server and each client
  - For example, the same pickup pad on a level will have the same object id on each client
- Assigning object ids
  - For static objects, they can be assigned ahead of time – all pick up pads are loaded in the same order on all clients.
    - Pickup pad 1 gets id 1, pad 2 gets id 2, etc.
  - For dynamic objects like spawned mobys, server has object creation functionality
    - Can ask server to assign an id for an object within a given range

Objects (continued)

- Changing object data



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Authority

- Refers to the client that the server has chosen to make state changes about an object
- Two types of authority, default and permanent

Authority (continued)

- Default authority
  - Authority can migrate from one client to another
  - When migration occurs
    - Object does not have an authority yet
    - Current authority is unresponsive or has disconnected
  - A client knows whether or not it's the authority of an object
  - Cannot reliably know who the authority is if it is another client

Authority (continued)

- Permanent authority
  - Once authority client is chosen, it does not change
  - If authority client disconnects, object is deleted
  - Commonly used for player-owned objects (deployable turrets, stat objects)

Authority (continued)

- Authority groups
  - Each object is part of a group and has a group id
  - A group can have multiple objects in it
  - Server assigns the authority of a group to a client, that client becomes authority of all objects in that group
  - Object whose authority is independent of other objects will be in its own group
  - Authority groups are useful when two or more objects should be updated by the same client
    - All bots are usually in same authority group because of the job system and nav reservations

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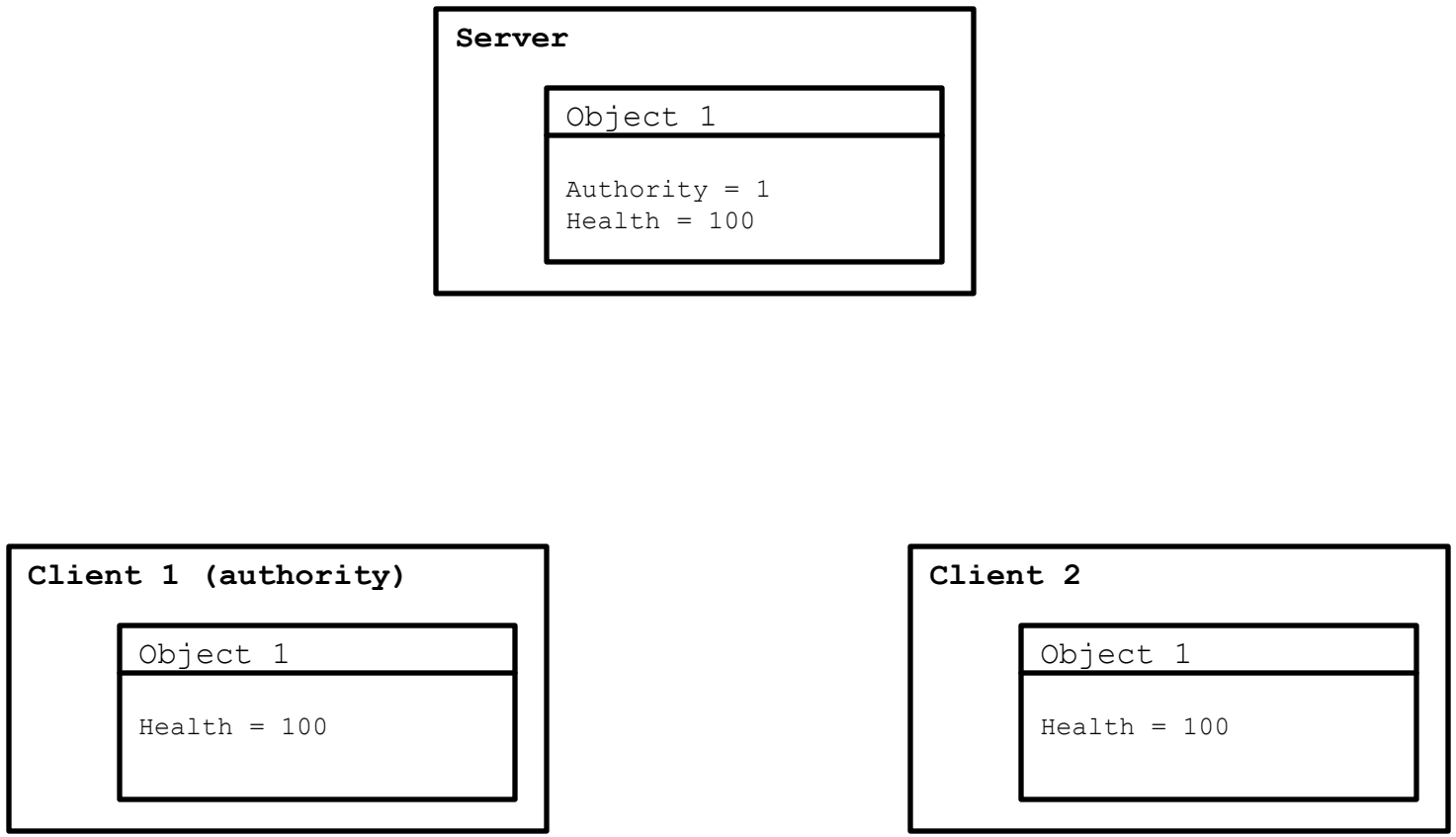
Updates

- Usually used for things that need periodic updates
  - Position changes for a moby, state changes for a bot
  - Server will take update and forward it to clients
- Sent only by the authority, client-side logic usually comprises
  - Check if we're the authority
  - If so, run some logic to determine changes that need to be made (e.g. move position 1 meter)
  - Send changes to server
- If a non-authority sends an update, the server will discard it

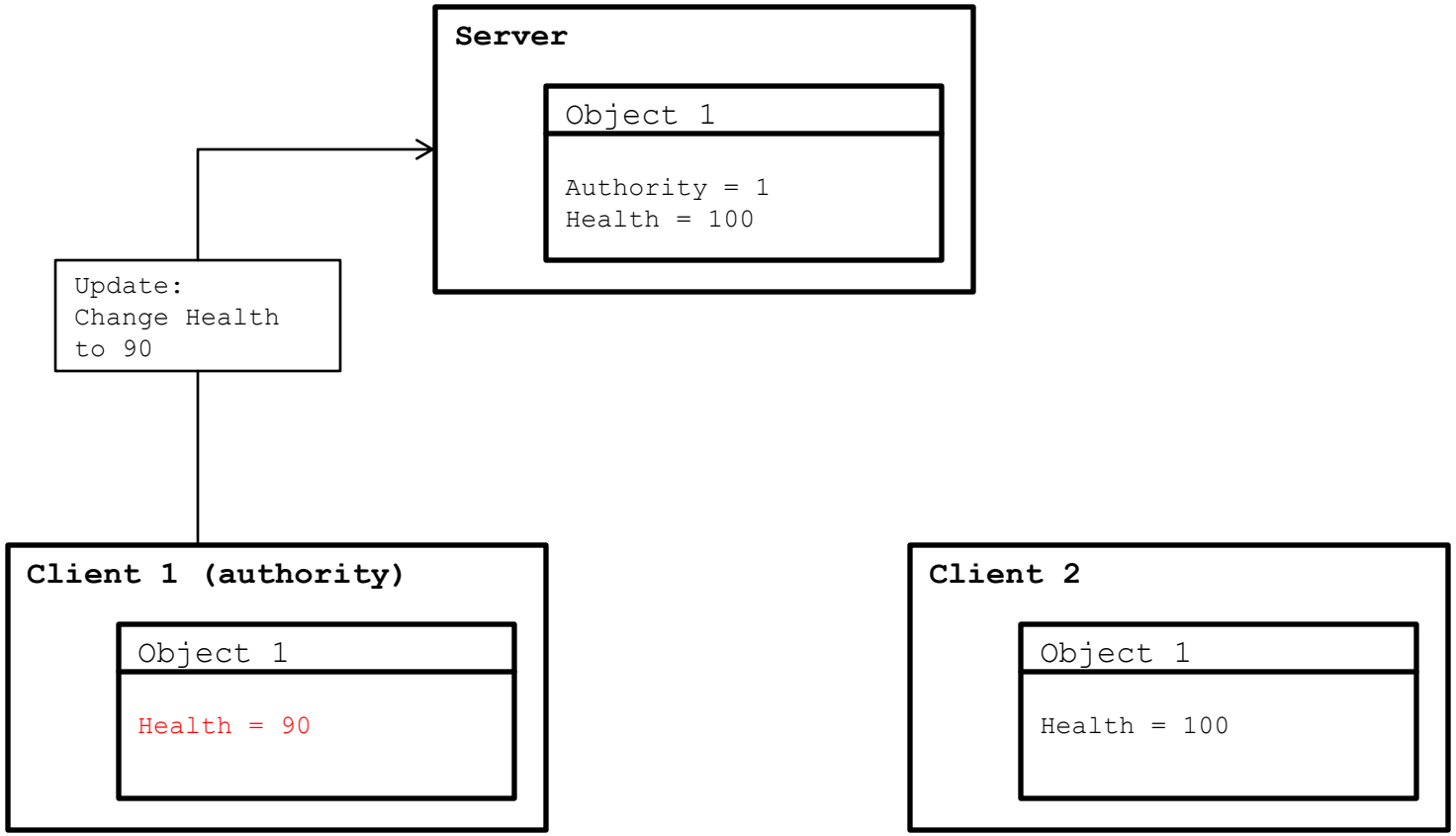
Updates (continued)

- Example: Burning Car
  - Car has object id = 1
  - Starts with 100 health
  - Health is reduced by 10 points per second

Updates (continued)



Updates (continued)



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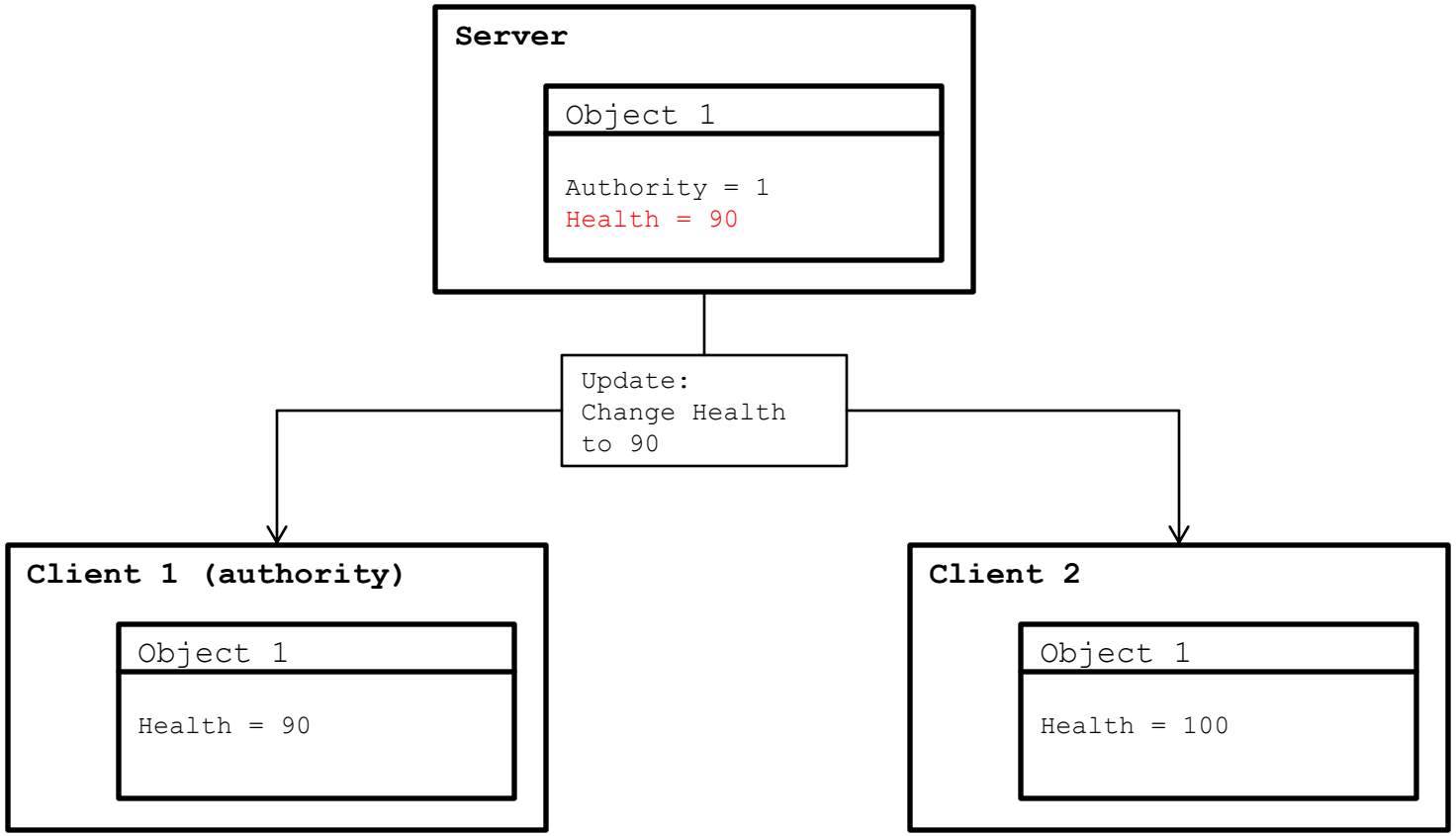

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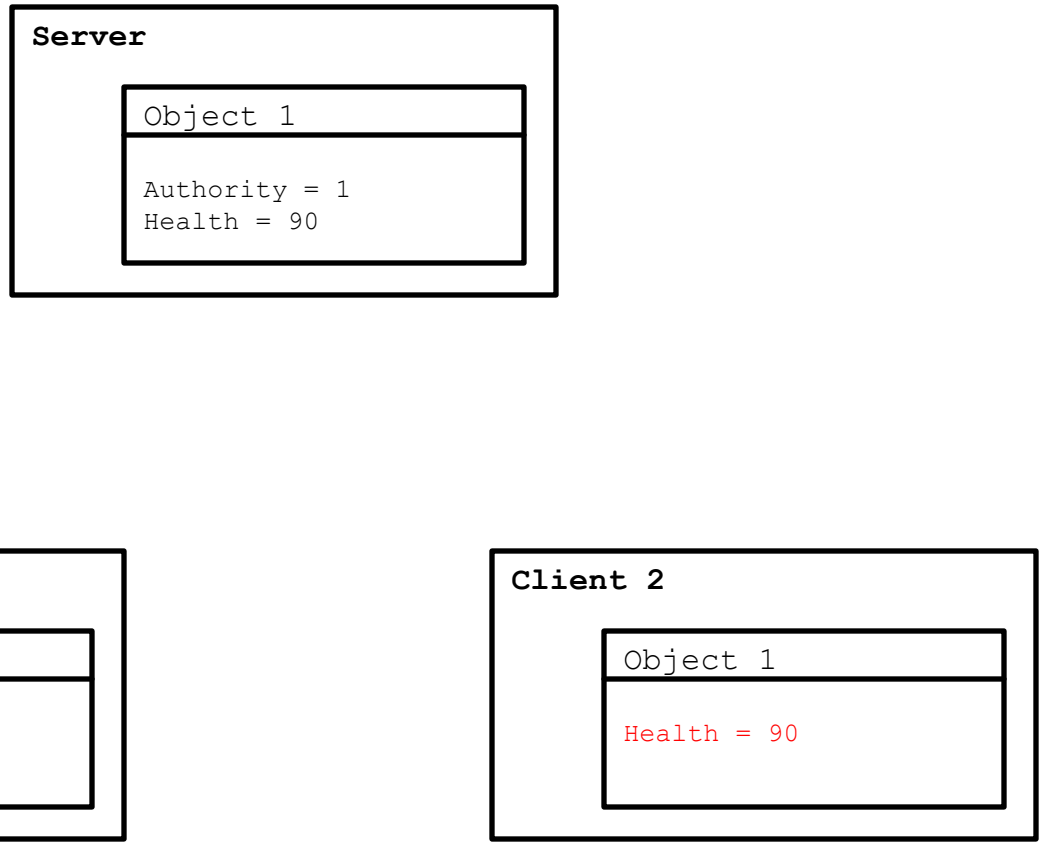


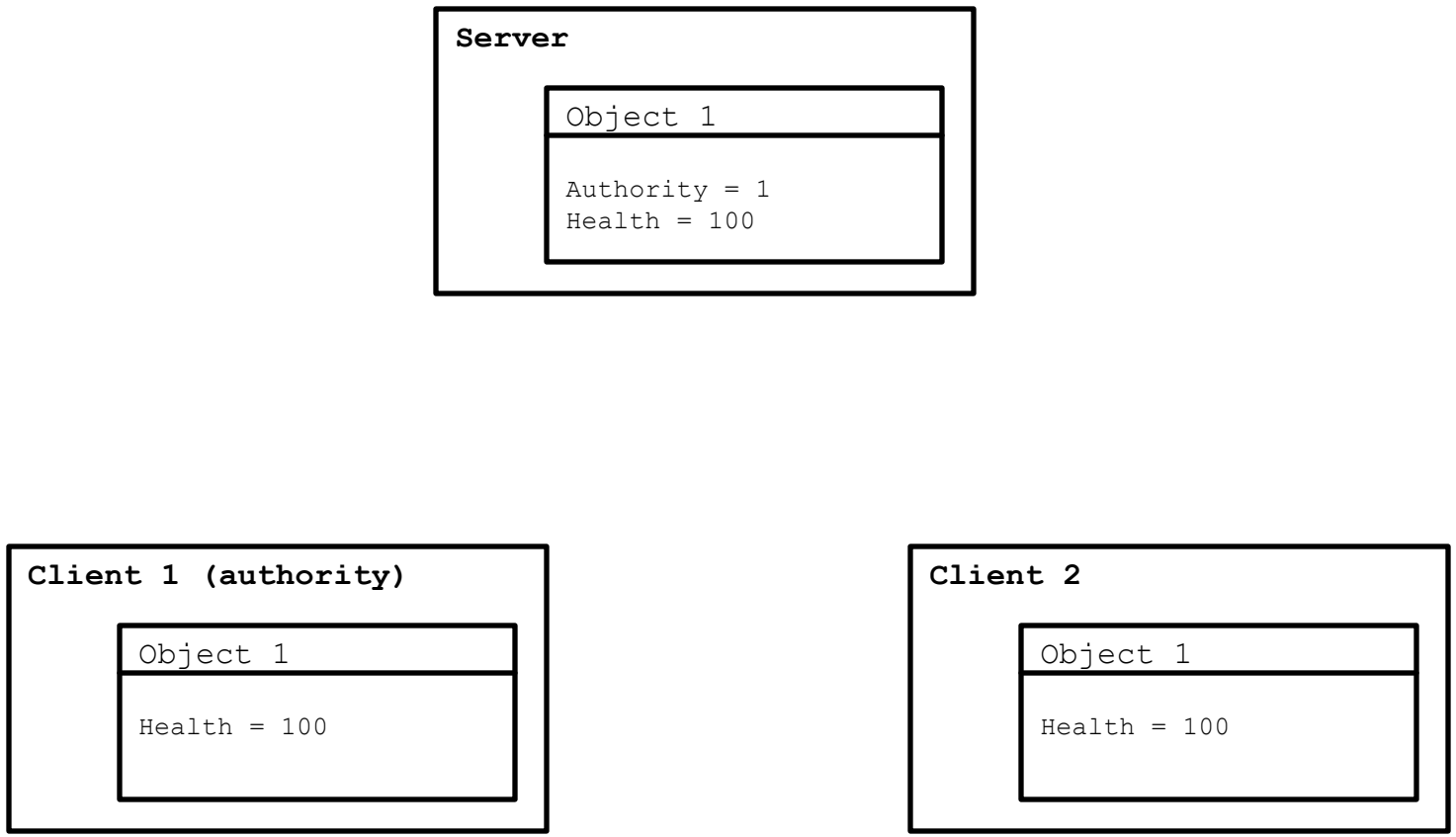
Updates (continued)

- Problem: what happens if the client sending the change loses authority
  - Server will reject health change to 90 since they are no longer the authority
  - But locally, the client has already changed health to 90, leaving them in an inconsistent state with other clients

Updates (continued)

- Solution: only send change requests to the server without modifying any local state
  - Authority sees the car has 100 health, knows that it should be 90 and sends change to server
  - Server gets message, changes health to 90, forwards change back to all clients, including authority
  - If authority changes, server will reject change but all clients remain consistent

Updates (continued)



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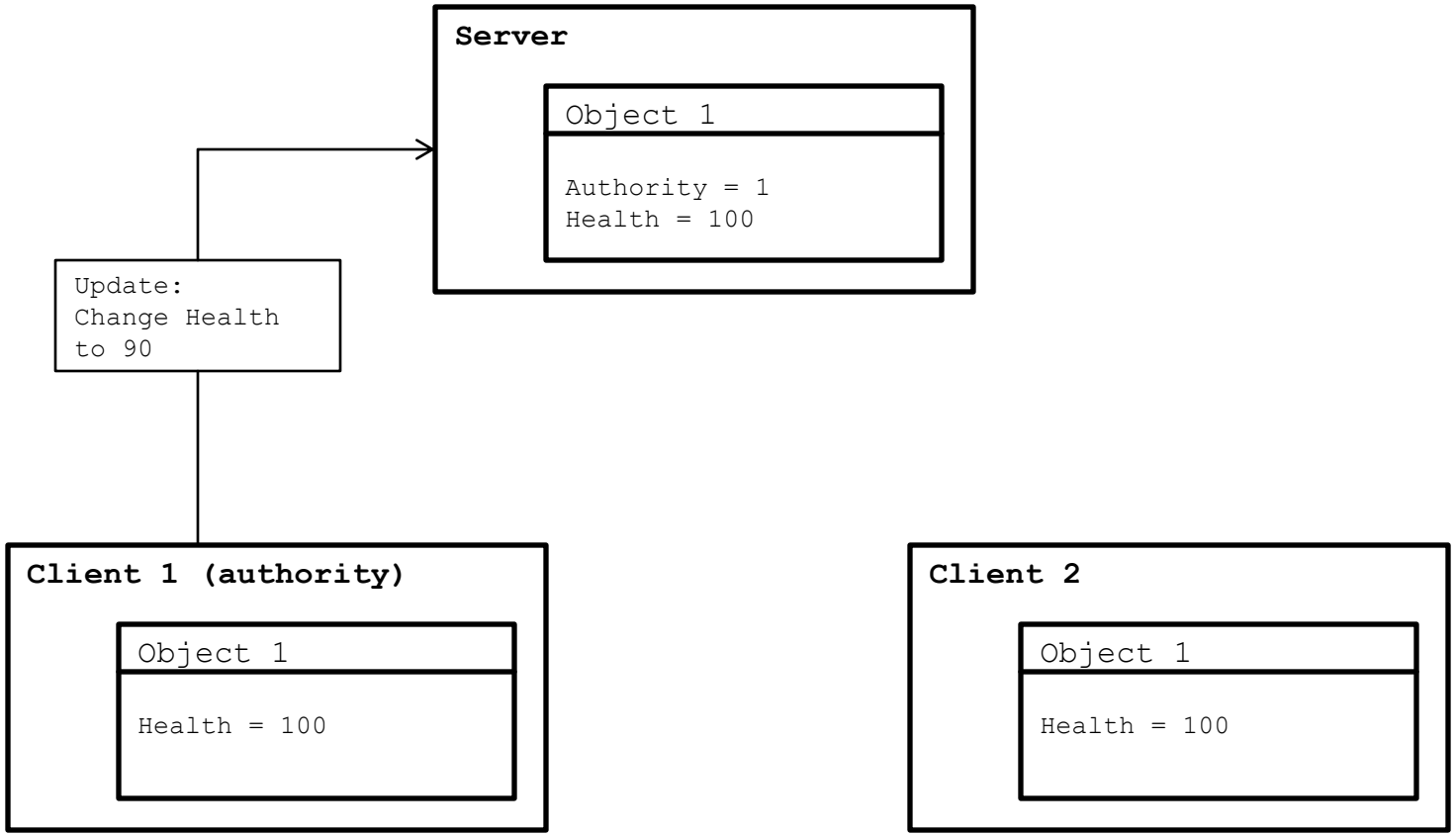

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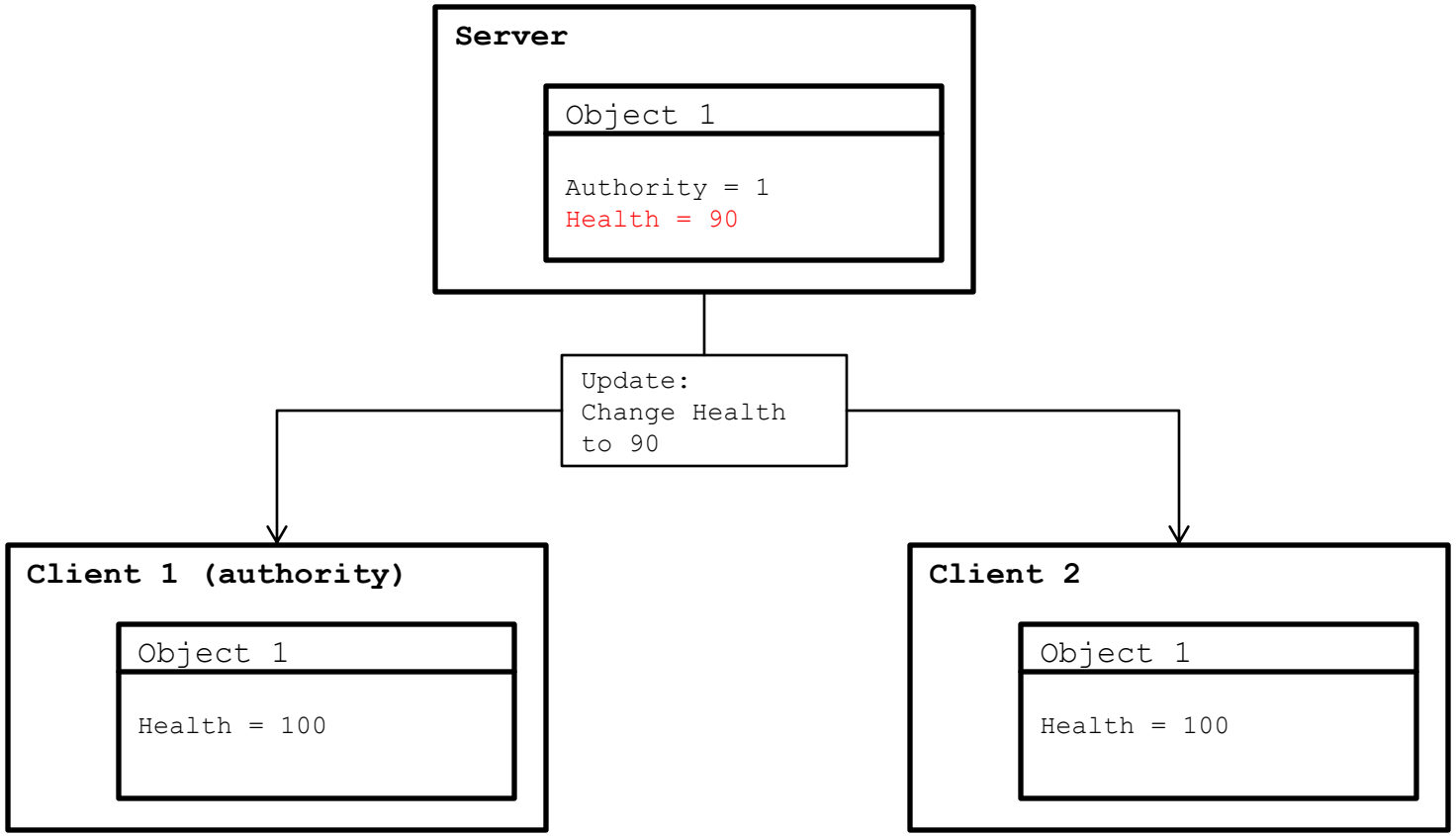

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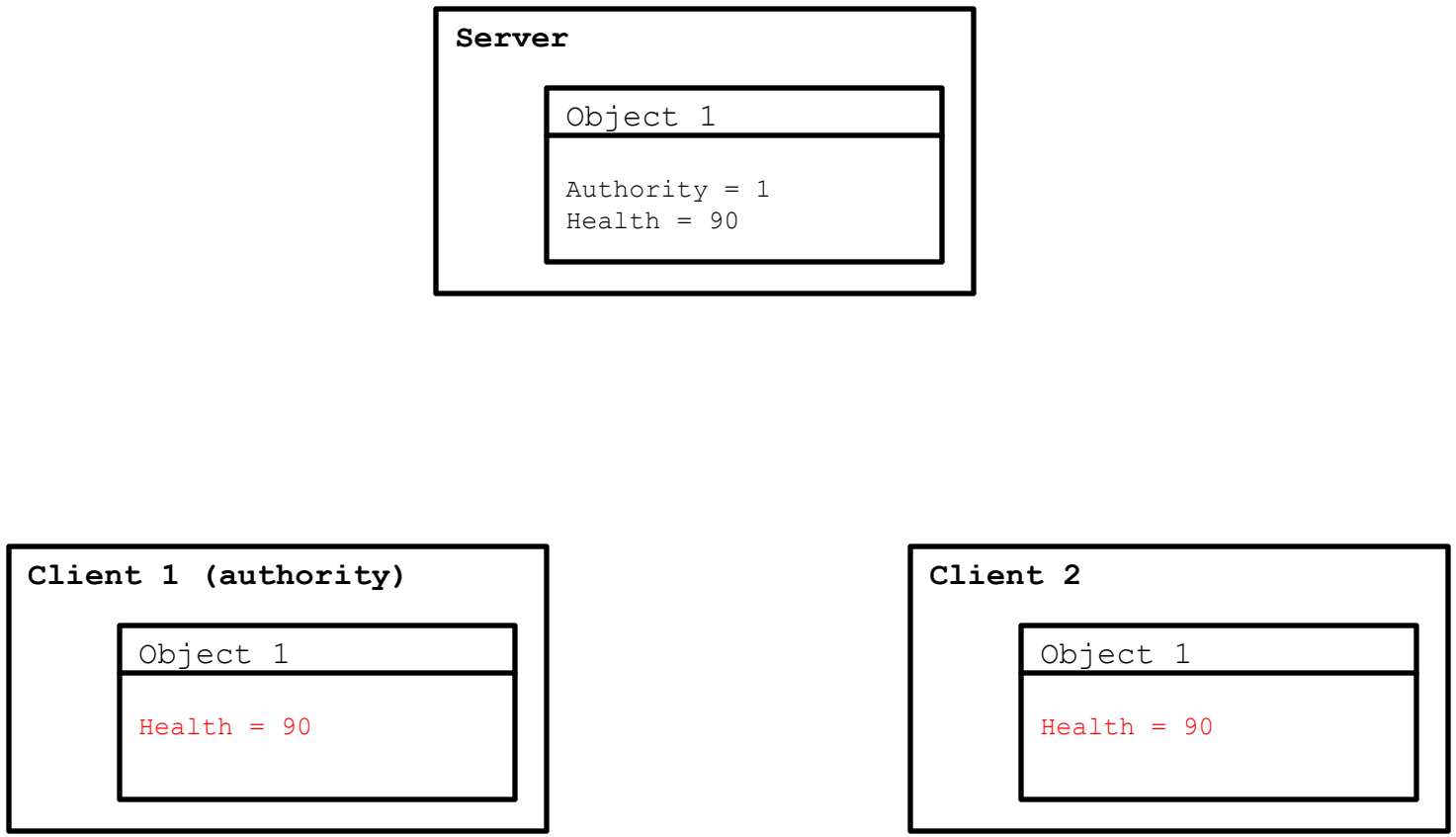


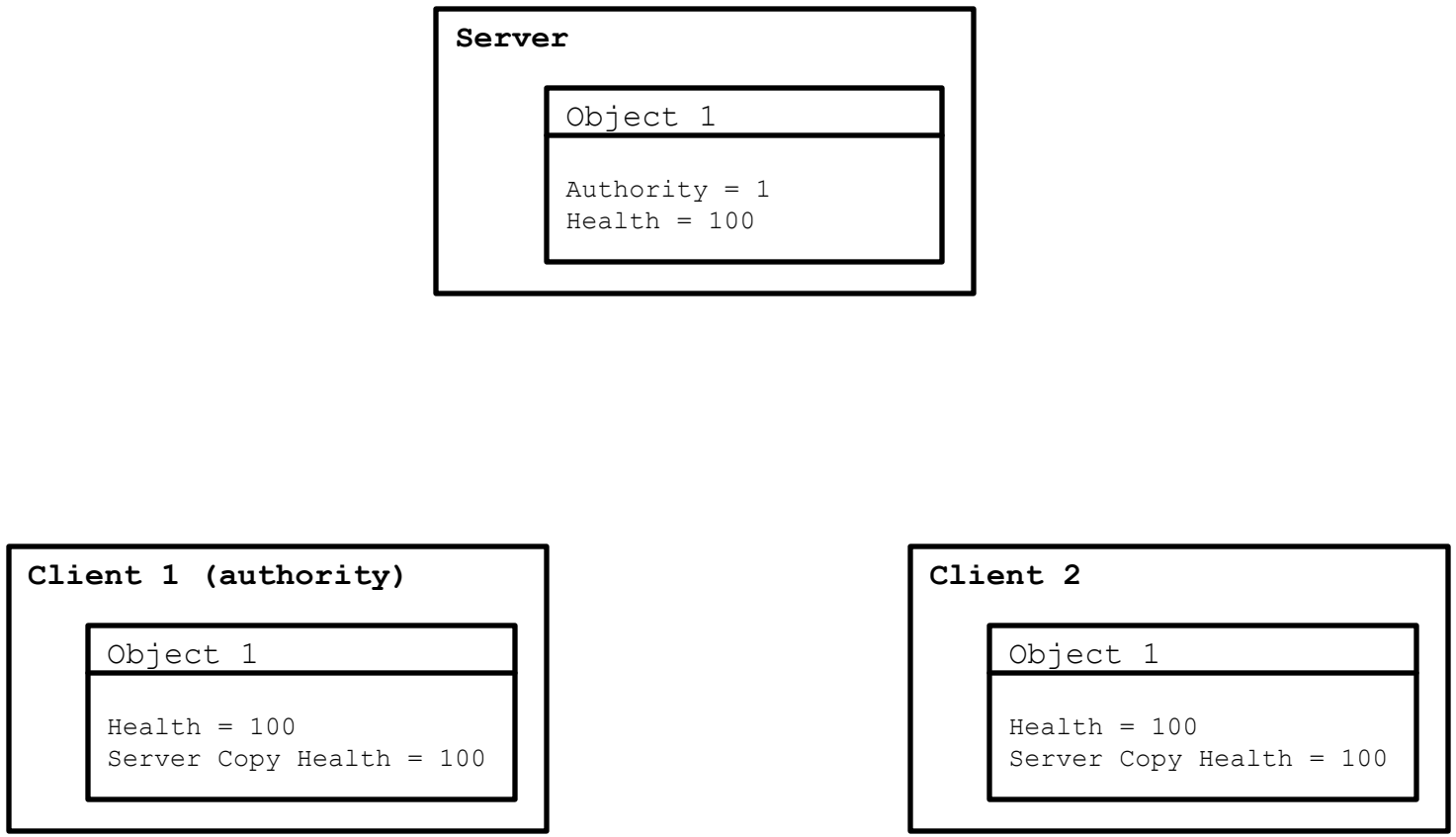
Updates (continued)

- Problem: multiple updates are not queued properly
  - Authority sees car has 100 health, deducts 10 points, sends request to server to change it to 90
  - 1 second later, server has not responded with change yet, so the authority still sees 100 health
  - Server finally sees first update, changes health to 90 and forwards it to clients
  - Server then sees second update, changes health to 90 and forwards it to clients
  - Health gets set to 90 instead of 80

Updates (continued)

- Solution: maintain second copy of each field on the client, known as the server copy
  - Server copy of a field contains the change that was last sent to the server
  - When a non-authority client receives an update, their server copy is overwritten with the change as well
  - Regular game logic still relies on regular copy

Updates (continued)



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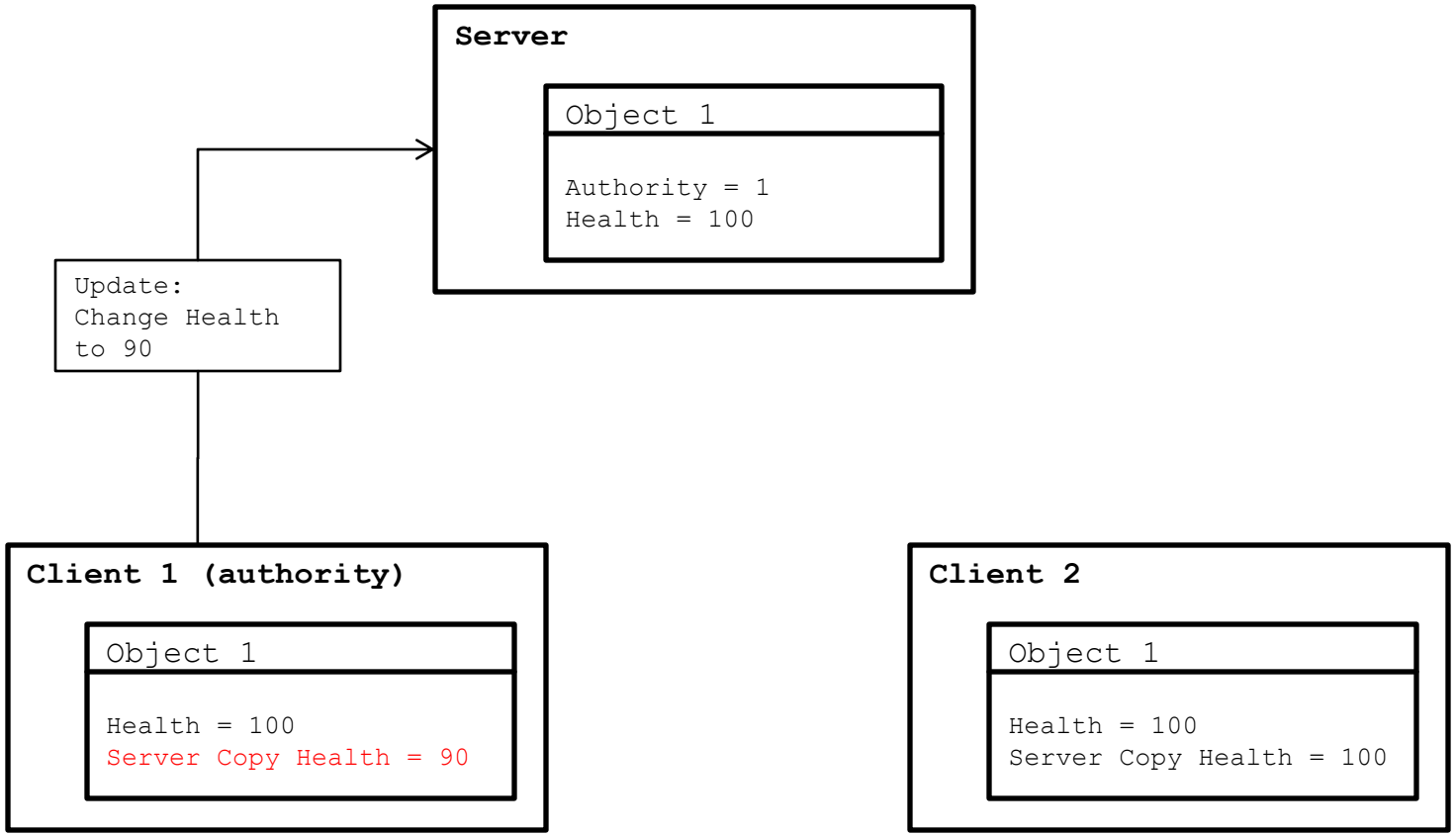

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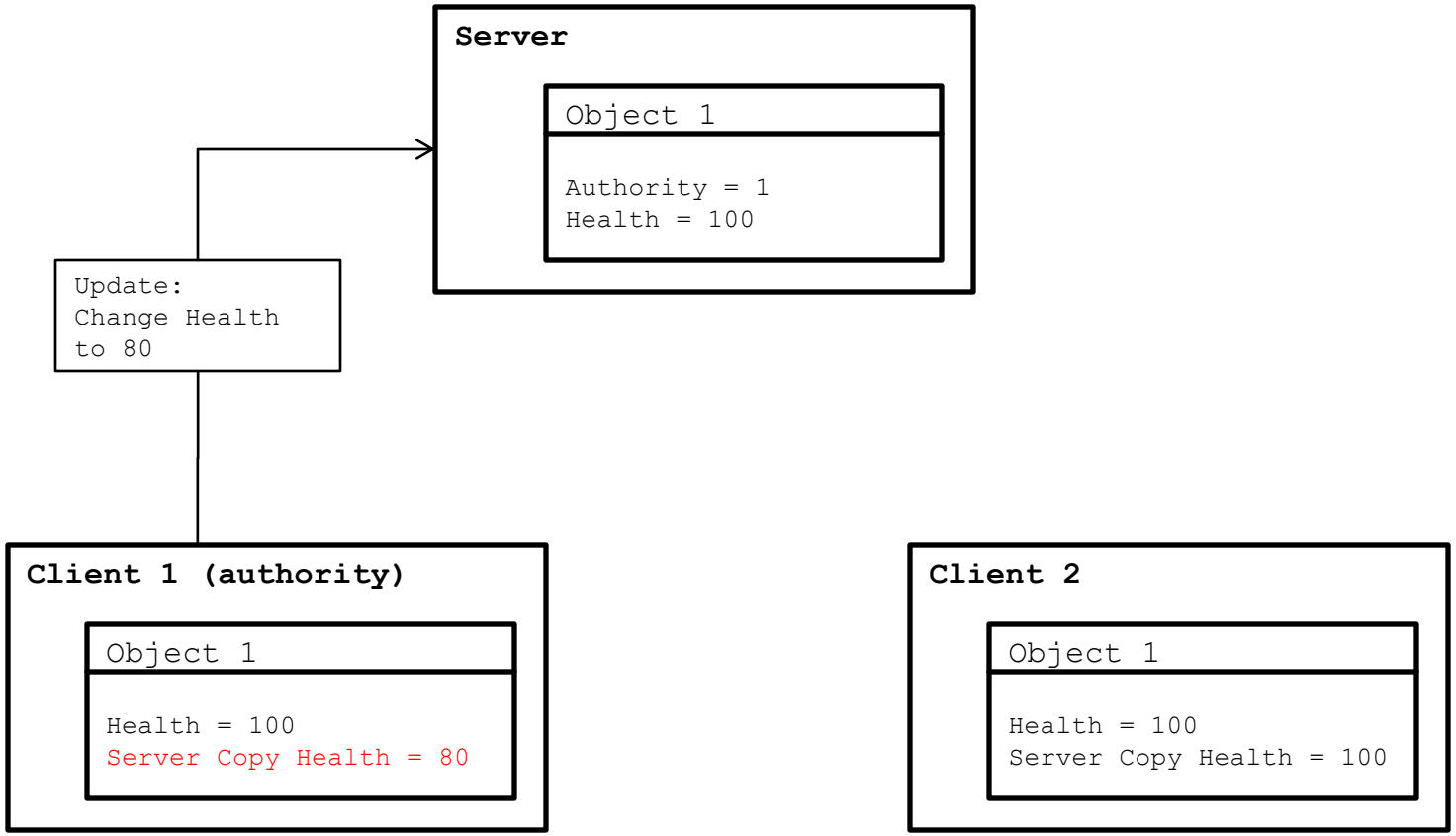

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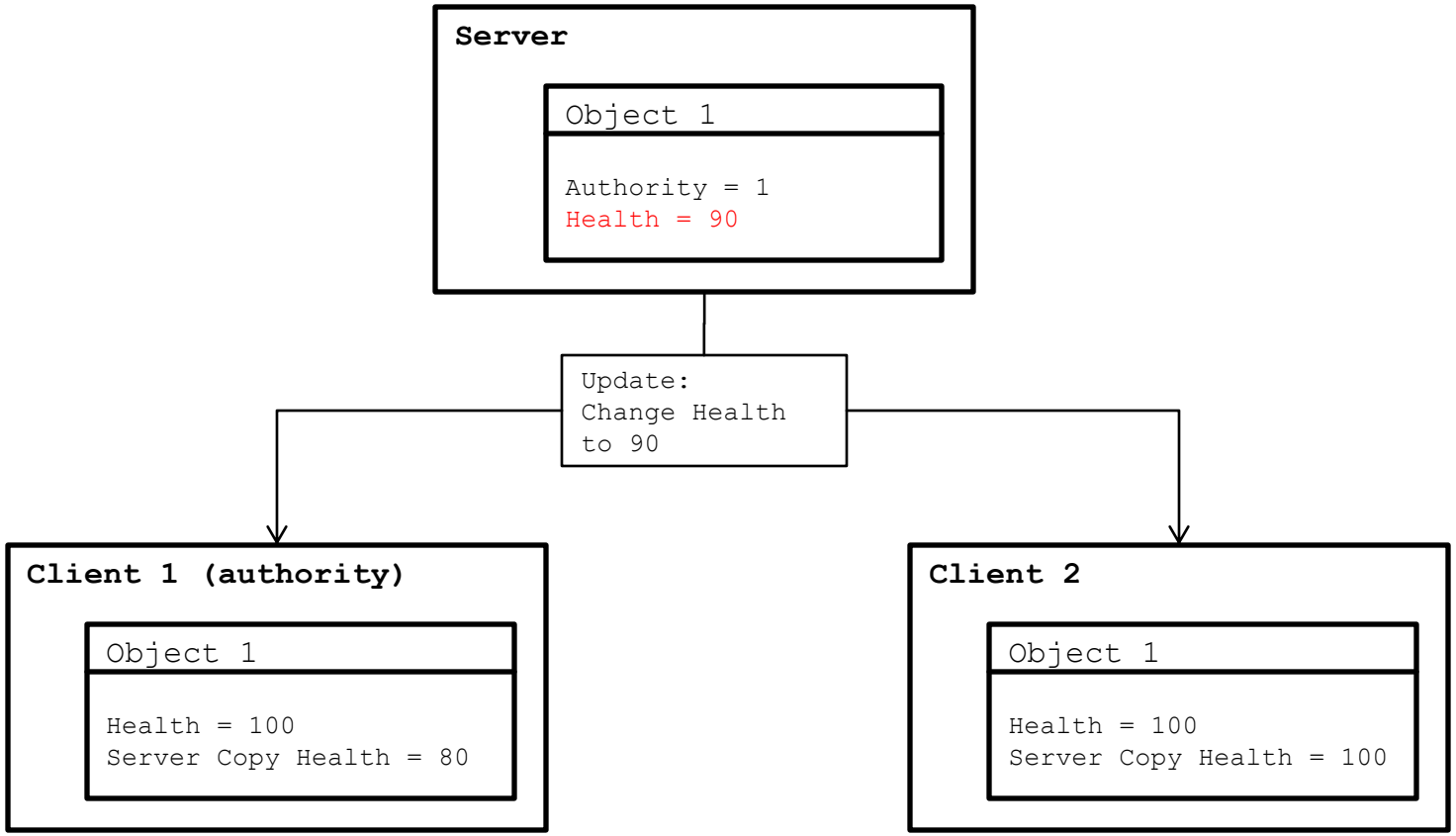

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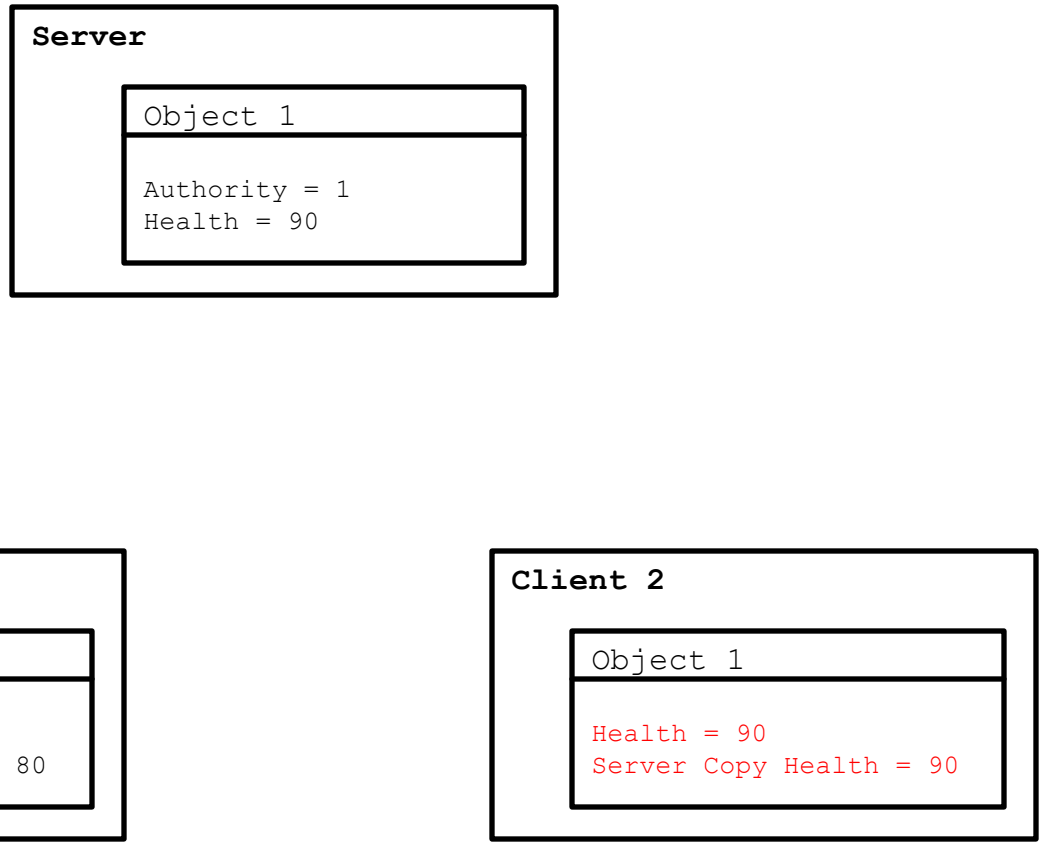

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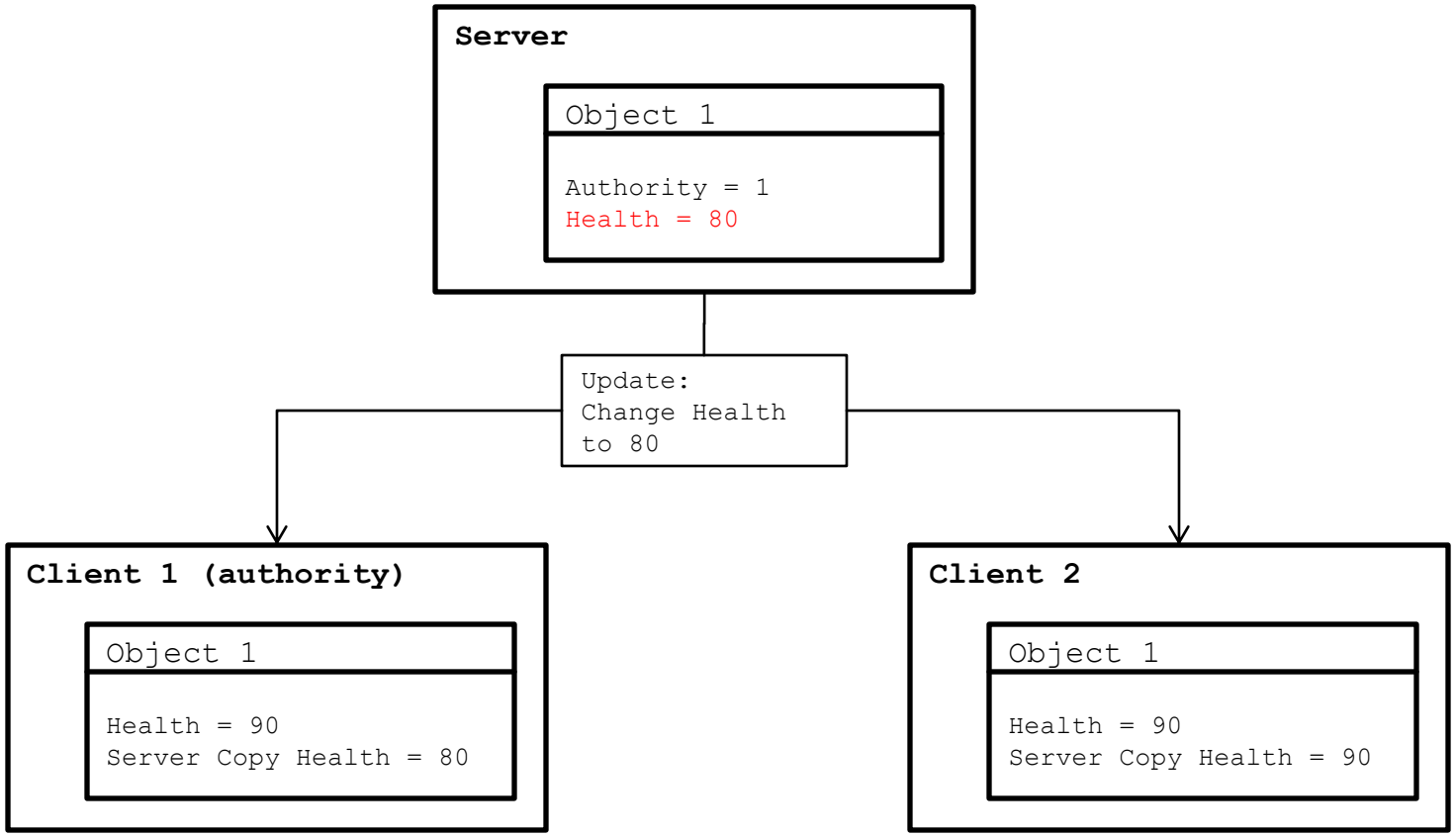

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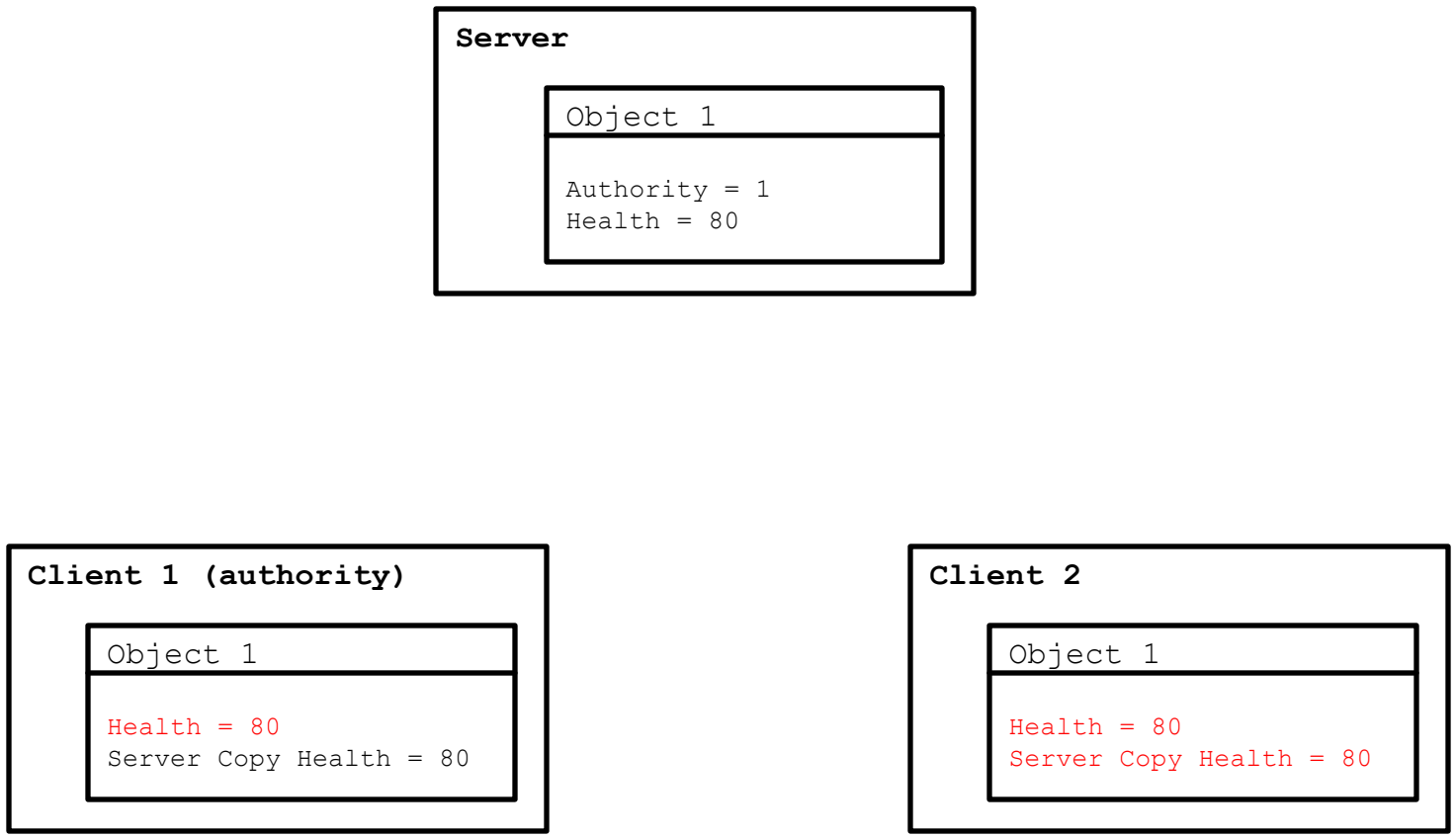

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Events and Responses

- A client can send an event on an object to request a change to it
  - Any player can damage a bot – damage messages are events
  - Any player can pick up a weapon – pickup requests are events

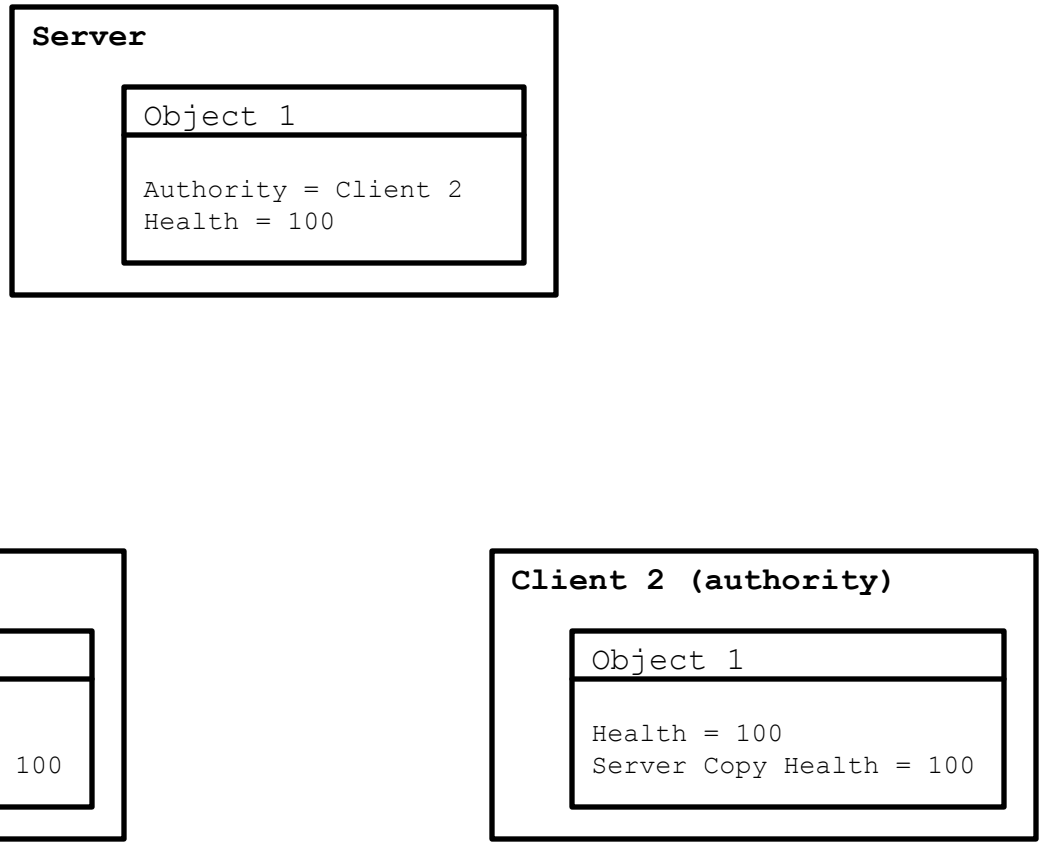
Events and Responses (con't)

- Events routed though server
  - Client 1 sends event to server on object
  - Server determines authority of object
  - Server forwards event to authority
  - Authority handles event and sends a response that contains state changes on the object
  - Responses are similar to updates

Events and Responses (con't)

- Multiple event types are supported per object
- Each event is defined with an event id
  - An object can have a damage event that represents a request from a client to reduce health
  - Same object can have a repair event that is a request to increase health
  - Damage and repair events would have different ids

Events and Responses (con't)



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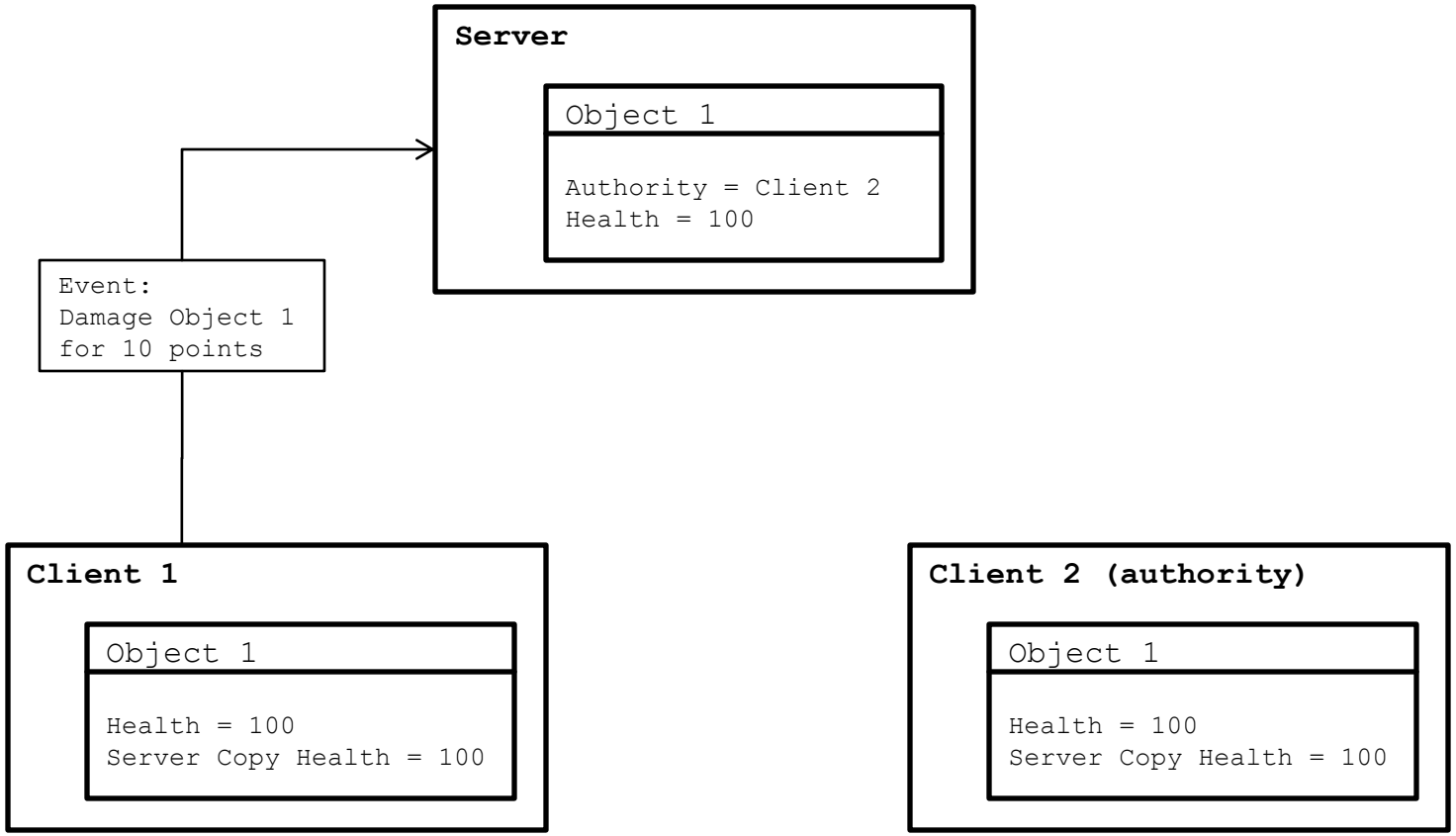

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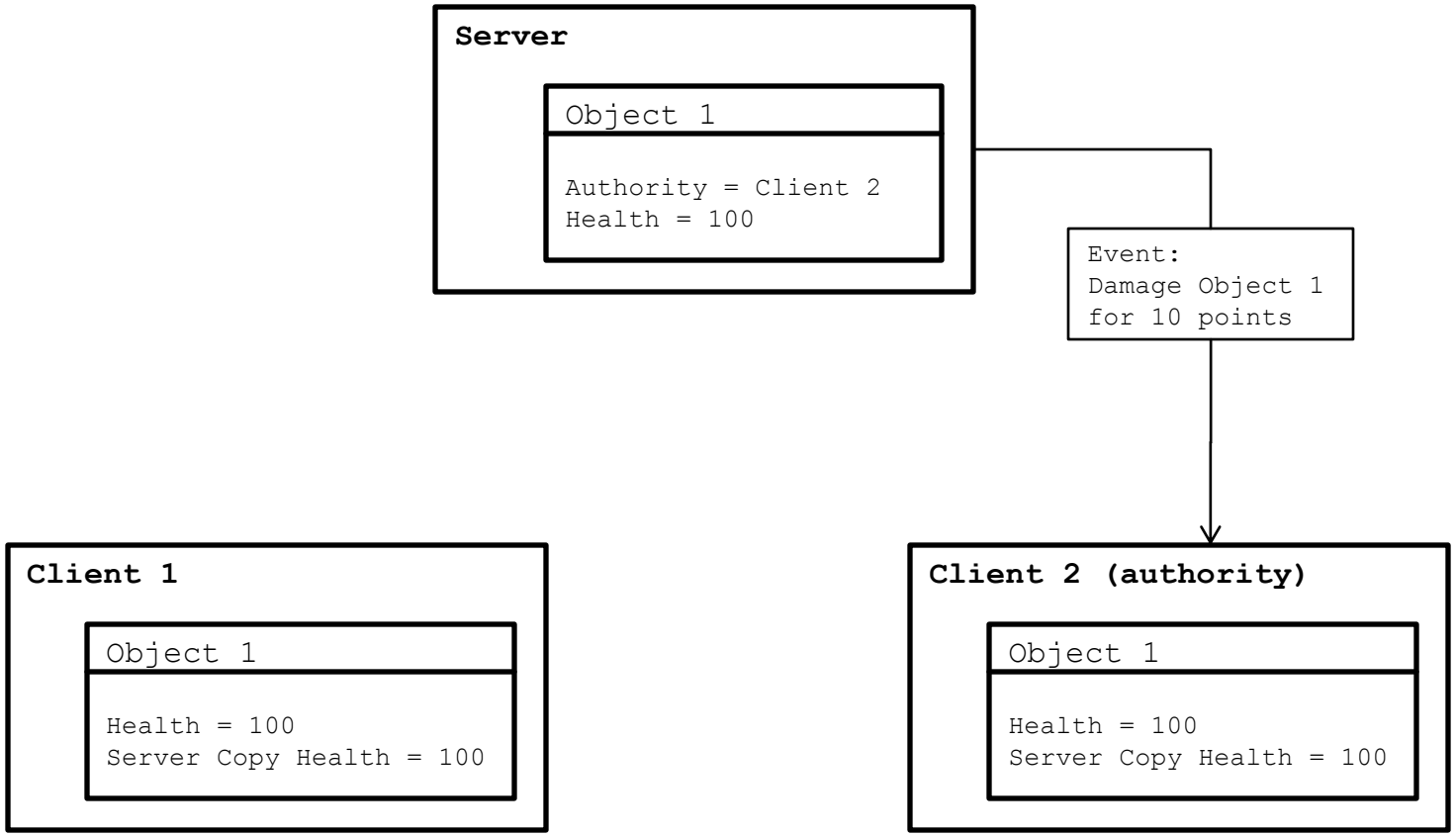

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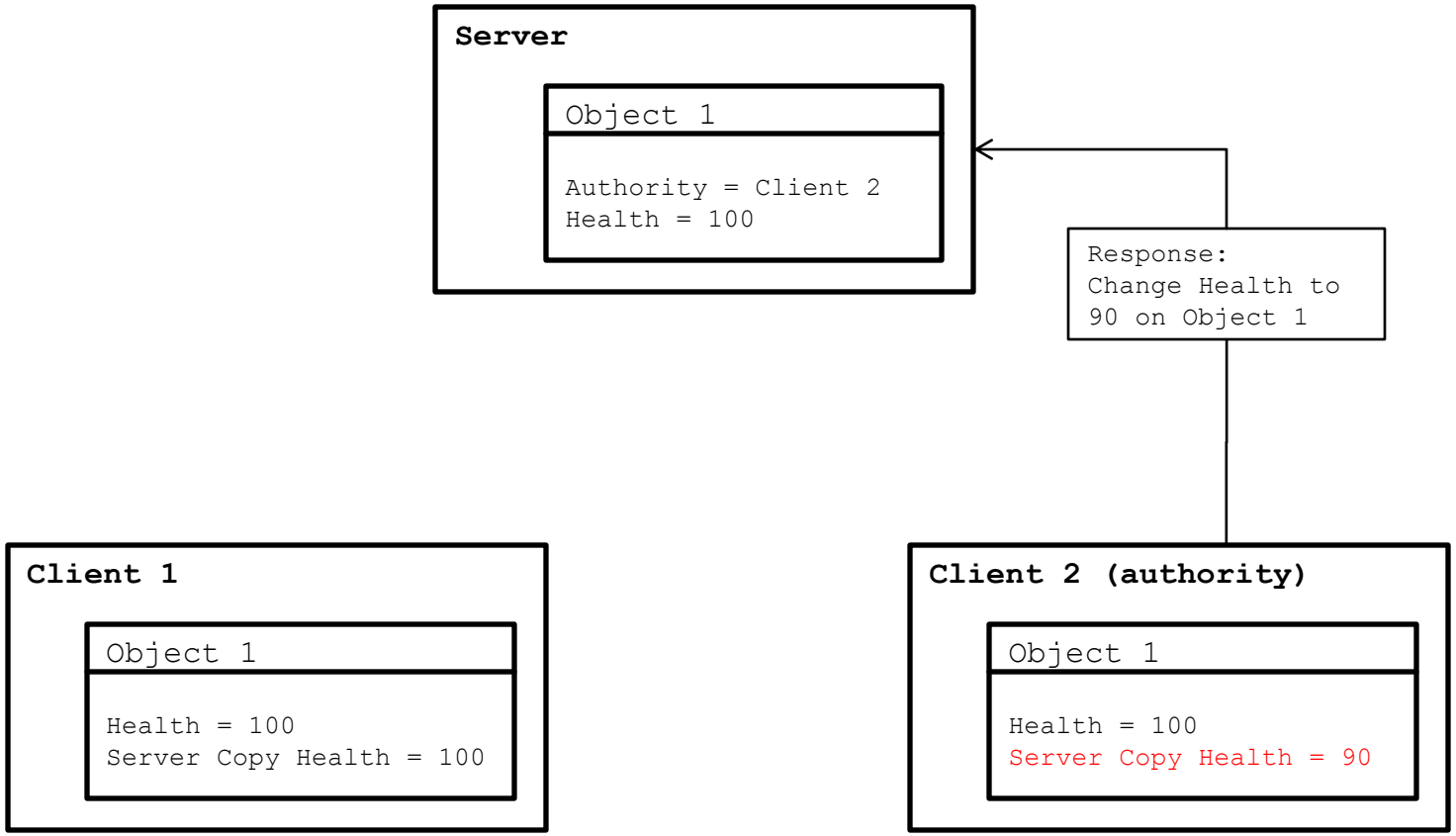

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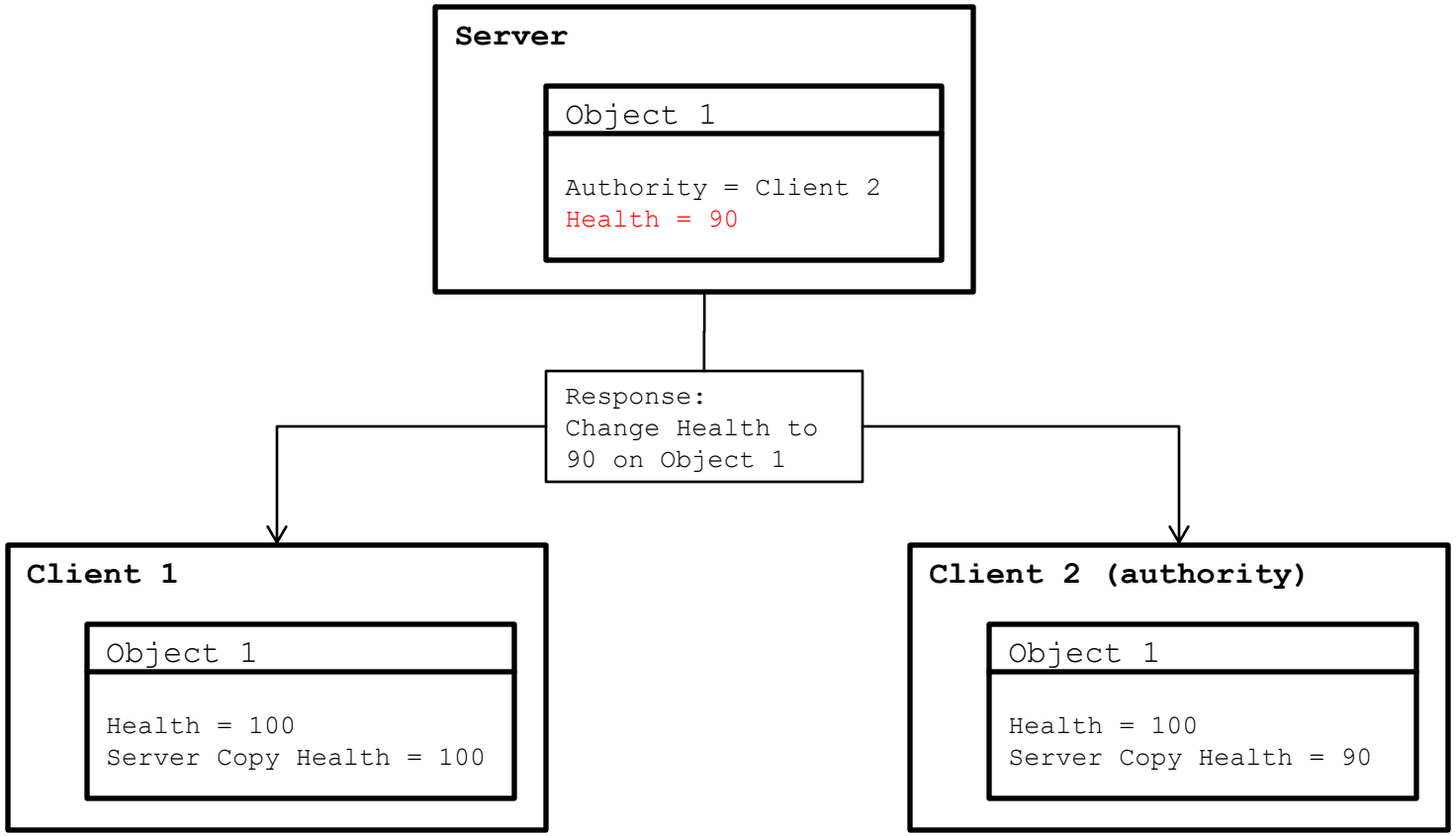

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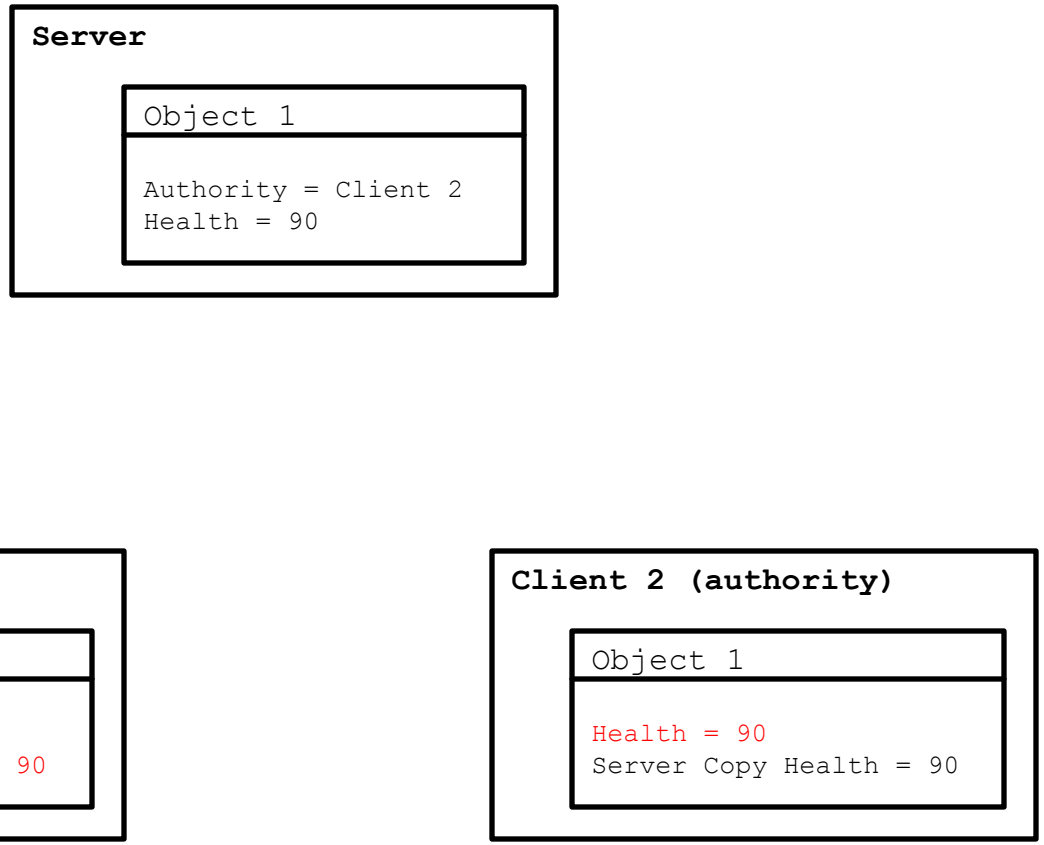

Events and Responses (con't)

- An event is effectively a message that gets the authority of an object to send an update

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Client API

- Sync data classes
  - Static object that defines a set of fields and message handlers
  - All instances of the same update class share the same sync data class

Client API (continued)

- Sync managers
  - A sync manager is allocated for each object on the client that needs to be synced
  - Majority of sync host API operates through a sync manager
  - Contains instance-specific data
    - Pointer to object being synced
    - Pointer to sync data class
    - Object id
    - Group id

Client API (continued)

- Example: DamageableCar update class
  - Can take damage, which reduces its health
  - Health also reduces by `10` points per second
  - Has a single synced field, m_health, with field id `0`
  - Has a single event type, damage, with event id `0`

Client API (continued)

- Sample synced update class

```
////////////////////////////////////////////////////////////////////////////////
// DamageableCar - update class for exploding car that can be damaged
////////////////////////////////////////////////////////////////////////////////

// Simple damage event sent for cars
struct DamageEvent : public Sync::SyncEvent
{
  f32 m_damage_amount;
};

class DamageableCar : public GameMobyUpdate
{
public:
  // Synced field ids
  enum
  {
    FIELD_HEALTH = 0
  };

  // Event ids
  enum
  {
    EVENT_DAMAGE = 0
  };
```

Client API (continued)

- Sample synced update class (continued)

```
  virtual void Init();
  virtual void Update();
  virtual void Delete();
  virtual void ProcessDamage( DMG::DamageResult* p_dmg_result );

  // Update handler
  static HandleSyncUpdate( Sync::SyncUpdate* p_update, DamageableCar * p_car );

  // Damage event/response handlers
  static void HandleDamageEvent( DamageEvent* p_event, DamageableCar * p_car );
  static void HandleDamageResponse( Sync::SyncResponse* p_response, DamageableCar * p_car );

protected:
  // Handle to sync manager
  Sync::ManagerHandle m_sync_manager_handle;

  // Synced health field
  f32 m_health;

  // Timer to do damage-over-time
  f32 m_dot_timer;
};
```

Sync data class

```
////////////////////////////////////////////////////////////////////////////
// DamageableCar sync data class - defines what fields on are synced on the
// update class and what message handlers it uses
////////////////////////////////////////////////////////////////////////////

// Starts sync class declaration - sync class is referenced by the name
// passed into the macro
DECLARE_SYNC_CLASS( DamageableCarSyncClass )

  // Field registration - needs name of class fields are on
  BEGIN_FIELDS( DamageableCar )
    // Register fields - requires a field id and member name
    REGISTER_FIELD(DamageableCar::FIELD_HEALTH, m_health );
  END_FIELDS

  // Register update handler - requires message handler
  REGISTER_STATIC_UPDATE_HANDLER( DamageableCar::HandleSyncUpdate )

  // Register event and response handlers - requires an event id and message handler
  REGISTER_STATIC_EVENT_HANDLER( DamageableCar::EVENT_DAMAGE,
    DamageableCar::HandleDamageEvent );
  REGISTER_STATIC_RESPONSE_HANDLER(DamageableCar::EVENT_DAMAGE,
    DamageableCar::HandleDamageResponse );

END_SYNC_CLASS( DamageableCarSyncClass )
```

Client API (continued)

- Sync manager allocation/de-allocation

```
void DamageableCar::Init()
{
  GameMobyUpdate::Init();
  m_health = 100.0f;

  // Allocate sync manager - requires a pointer to a sync data class
  // which can be referenced with the GET_SYNC_CLASS macro
  Sync::SyncManager* p_manager = Sync::CreateManager(
    GET_SYNC_CLASS( DamageableCarSyncClass ) );

  // Pass pointer to our self to sync manager so it can reference synced
  // fields
  p_manager->Init( this );

  // Use server-copy of data when syncing fields
  p_manager->AllocServerCopy();

  // Store handle
  m_sync_manager_handle = p_manager->GetHandle();
}


void DamageableCar::Delete()
{
  // De-allocate sync manager
  Sync::FreeManager( m_sync_manager_handle );

  GameMobyUdpate::Delete();
}
```

Client API (continued)

- Update example

```
void DamageableCar::Update()
{
  GameMobyUpdate::Update();

  // Get sync manager
  Sync::SyncManager* p_manager = Sync::GetSyncManager( m_sync_manager_handle );

  // Check if we're the authority of the object
  if( p_manager && p_manager->IsAuthority() )
  {
    // Only the authority runs the below code

    // Reduce health 10 points per second
    if( TIME::DecTimer( &m_dot_timer ) )
    {
      // Determine the amount of health we last updated the server with
      f32 server_copy_health;
      p_manager->GetServerField( DamageableCar::FIELD_HEALTH, &server_copy_health );

      // Still have health, send update
      if( server_copy_health > 0.0f )
      {
         Sync::SyncUpdate sync_update;

         // Update server copy of health
         server_copy_health = Maxf( server_copy_health - 10.0f, 0.0f );
         p_manager->SetServerField( DamageableCar::FIELD_HEALTH, &server_copy_health );

         // Mark health as a field to sync
         sync_update.SendField( DamageableCar::FIELD_HEALTH );

         // Send update
         p_manager->Update( &sync_update );
      }

      // Reset dot timer
      m_dot_timer = 1.0f;
    }
  }
}
```

Client API (continued)

```
////////////////////////////////////////////////////////////////////////////
// This function gets called on all clients after the authority sends an
// update
////////////////////////////////////////////////////////////////////////////
void DamageableCar::HandleSyncUpdate( Sync::SyncUpdate* p_update, DamageableCar * p_car )
{
  // Trigger some effects if we've taken too much damage
  if( p_update->FieldIsModified( DamageableCar::FIELD_HEALTH ) )
  {
    if( p_car->m_health <= 50.0f && !p_car->HasTrackedEffects( EventType::SMOKING ) )
    {
      p_car->TriggerTrackedEffectEvent( EventType::SMOKING );
    }
  }
}
```

Client API (continued)

- Event-response example

```
////////////////////////////////////////////////////////////////////////////////
// This function gets called when any local client damages the car - sends off
// an event to the authority with the amount of damage we want to do
////////////////////////////////////////////////////////////////////////////////
void DamageableCar::ProcessDamage( DMG::DamageResult* p_dmg_result )
{
  // Get sync manager
  Sync::SyncManager* p_manager = Sync::GetSyncManager( m_sync_manager_handle );
  if( p_manager )
  {
    // Build sync event to pass damage amount
    DamageEvent dmg_event;
    dmg_event.m_damage_amount = p_dmg_result->m_damage.m_amount;

    // Send event - the first argument is the event id, which will determine
    // which event handler gets called with this event on the authority
    // client
    p_manager->Event( DamageableCar::EVENT_DAMAGE, &dmg_event );
  }
}
```

Client API (continued)

```
////////////////////////////////////////////////////////////////////////////////
// This function gets called on the authority client when any client sends
// a damage event on this damageable car
////////////////////////////////////////////////////////////////////////////////
void DamageableCar::HandleDamageEvent( DamageEvent* p_damage_event, DamageableCar* p_car )
{
  // Get sync manager
  Sync::SyncManager* p_manager = Sync::GetSyncManager( p_barrel->m_sync_manager_handle );
  if( p_manager )
  {
    // Build sync response
    Sync::SyncResponse sync_response;

    // Get current health
    f32 server_copy_health;
    p_manager->GetServerField( DamageableCar::FIELD_HEALTH, & server_copy_health );

    // Check if we're still alive
    if( server_copy_health > 0.0f )
    {
       // Update server copy of health
       server_copy_health = Maxf( server_copy_health - p_damage_event->m_damage_amount, 0.0f );
       p_manager->SetServerField( DamageableCar::FIELD_HEALTH, &server_copy_health );

       // Mark health as a field to sync
       sync_update.SendField( DamageableCar::FIELD_HEALTH );
    }

    // Send response - uses same event id we used when sending original event
    // always gets sent so server can resolve events
    p_manager->Response( DamageableCar::EVENT_DAMAGE, &sync_response );
  }
}
```

Client API (continued)

```
////////////////////////////////////////////////////////////////////////////////
// This function gets called on all clients after the authority has handled
// a damage event and decremented the health of the car
////////////////////////////////////////////////////////////////////////////////
void DamageableCar::HandleDamageResponse( Sync::SyncResponse* p_response, DamageableCar * p_car )
{
  // Trigger some effects if we've taken too much damage
  if( p_response->FieldIsModified( DamageableCar::FIELD_HEALTH ) )
  {
    if( p_car->m_health <= 50.0f && !p_car->HasTrackedEffects( EventType::SMOKING ) )
    {
      p_car->TriggerTrackedEffectEvent( EventType::SMOKING );
    }

    // Trigger a damaged event
    p_car->TriggerEffectEvent( EventType::DAMAGED );
  }
}
```