QuON

A Quad-Tree Based Overlay Protocol for Distributed Virtual Worlds

Stephan Krause & Helge Backhaus
Universität Karlsruhe - Institut für Telematik
Motivation

What more could you ask for?
Our goal

• One shared world for all players

• An arbitrary number of players in the game-world
Almost all MMOGs and Virtual Worlds use central server farms.

How to make it scale?
- **Sharding:** Multiple realms
  - World of Warcraft ~ 5,000 concurrent players/realm
- Lots of proxy servers
  - EVE online ~50,000 concurrent players

Additional drawback:
- Infrastructure is expensive
Possible solutions?

- Use P2P technologies:
  - Players communicate directly without central servers
- But how?
  - Fully meshed network does not work
  - Multicast does not help
    - $O(n^2)$ messages
→ „Interest Management“
- Deliver only “interesting” messages
Possible Solutions

- Simple idea: divide the map!
  - Messages will only be send to players in the current segment
- Chose some responsible node
  - Coordinates message dissemination
- To avoid overloading
  - Split the segment if it is too full
  - Use Application Layer Multicast
- Problems:
  - “Supernode” is single point of failure
    - Backup mechanisms are needed
  - Introduces additional delay
Mutual Notification

- **Area of Interest (AoI)**
  - Direct connection to all players inside AoI
  - Mutual notification of new neighbors
  - Problem: Direct neighbors not sufficient
    - Additional connections needed

- **Advantages:**
  - No bottlenecks or single points of failure
  - No arbitrary zones and zone borders
  - Optimal Delay (1 Hop)

- **Example (related work): VAST**
  - Uses a Voronoi diagram for classifying and discovering neighbors
QuON

- "Quad-tree based Overlay Network"
- Basic Idea: Mutual Notification
  - Direct Connections to all Neighbors inside AoI
  - Mutual notification of new neighbors
- To guarantee connectedness
  - One "Binding Neighbor" per quadrant
    - The closest neighbor in this quadrant
    - Is updated on every movement
    - Binding-neighbor information is exchanged periodically
      - This guarantees the closest possible binding neighbor will be found
    - "Soft-state Neighbors" for symmetric neighbor relationships
Excursus: (Point-Region) Quad-Tree

- Tree structure developed for 2D coordinates
- Each vertex can have up to 4 children
- Advantage: simple
- Easy computation of nearest neighbors
- In QuON: no globally valid quad-tree!
Neighbor classification

- is direct neighbor of
- are binding neighbor of
- is binding neighbor of
- is soft-state neighbor of
Finding new neighbors

- is neighbor of , who informs
- is binding neighbor of
- becomes new binding neighbor of before entering ‘s AoI
Joining/Leaving the Overlay

Join
- Connect to arbitrary bootstrap node
- Greedy forward until initial position is reached
  - Can be improved by position cache

Leave
- Graceful: Send leave notification to all neighbors
  - Contains a list with all neighbors
- Ungraceful: Failure will be detected by lack of update messages
  - Direct neighbors simply discard failed player
  - Binding neighbors replace failed player by next candidate
  - In rare cases → Backup needed
Backup Mechanisms

**Failures**
- Keep last binding neighbor outside of AoI as backup neighbor
- If binding neighbors fails
  - If still nodes inside AoI, one of them becomes new binding neighbor
  - Else if one soft-state neighbor is binding neighbor candidate, he will become new binding neighbor
  - Else connect to backup binding neighbor and get recursively forwarded to correct binding neighbor

**Latency**
- “AoI Buffer” when classifying neighbors
- Size depends on average latency and maximum move speed
Simulation Settings

- OverSim as simulation framework
- “Simple Underlay” using latencies from CAIDA’s skitter project
- 500 nodes
- 2 simulated hours
- Heavy tailed session times (100 min average)
- Playground size 1,000m*1,000m
- Movement speed 5m/s, 6 updates/sec
- Group based random waypoint
  - Group sizes from 1 to 40
Metrics

- **Connectedness**
  - Percentage of players that have at least one neighbor
  - Percentage < 100% → at least one player lost all connections to the overlay

- **Neighbor awareness**
  - Percentage of players with no missing neighbors
  - Percentage < 100% → at least one player is missing at least one of his neighbors

- **Bandwidth**
  - Average and maximum bandwidth

- **Latency**
  - Time until movement update reaches neighbors
  - One Hop → ~ 90ms in all settings
QuON is a new mutual notification protocol for MMOGs and Virtual Worlds

- No server or additional infrastructure needed
- Binding neighbors ensure connectedness and neighbor awareness
  - They are selected with the help of quad-trees
- Simulation results show practical performance
  - Perfect connectedness
  - Very good neighbor awareness
  - Does not exceed reasonable bandwidth requirements