Scalable Network Architecture in Virtual World Applications

Chao Wang
Advised by Jon Turner
Roadmap

• Background
• Our Network Architecture
• Conclusion
Virtual World and Its Applications

“A synchronous, persistent network of people, represented as avatars, facilitated by networked computers.”

– Mark W. Bell, Indiana University

• Entertainment / Education
• Organizational Presence
• Planning / Rehearsal

Related Works and How They Scale

• Second Life

Related Works and How They Scale

- Second Life
- Sirikata \[1\]

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World of Dynamic Objects

Photo by: Jleybov
World of Dynamic Objects
World of Dynamic Objects

- Donnybrook [1]

Review of Unicast/Multicast
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Roadmap

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• **Our Network Architecture**
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Our Virtual World App

- Update Status over Zone Multicast
Performance Requirements

• Three requirements
  • Each avatar’s report should be delivered to all other avatars within one second
  • Receive more frequent updates from avatars of interest
  • Constant total sending rate over zone multicast (say, 20 reports/sec)

• Each avatar also sends reports over his private multicast
• Avatar subscribes to 5 nearest peers’ private multicasts
• Each avatar will attach to his report what he learned
Piggybacked Information

ID: a (ax,ay)
...

ID: b (bx,by)
...

ID: c (cx,cy)
...
{(a,ax,ay), (b,bx,by)}

ID: d (dx,dy)
...
{(a,ax,ay), (b,bx,by), (c,cx,cy)}
Gossiping over Private Multicast
Gossiping over Private Multicast
Gossiping over Private Multicast
The Critical Path of Gossiping

- \( f \) reports/sec = the sending rate over private multicast
- A report can reach all avatars in one second if the length of the critical path is less than \( f \)
Reducing the Critical Path

• Idea: add shortcuts
  (i.e., add additional directed edges on each vertex)

• In the context of virtual world app, it means each host will subscribe to some additional multicasts

• Two approaches:
  • Subscribe to other host in the virtual world
  • Subscribe to a cluster of highly-connected servers
Building Highly-Connected Clusters

- Each host unicasts his status update to one of servers in the cluster
- Each server will multicast the update to some other servers, and will multicast the update to some hosts
- Length of critical path in the cluster determines the sending rate
Building Highly-Connected Clusters

- Coterie: Let $C = \{p_1, p_2, \ldots, p_n\}$. A set of subsets $Q_i$ of $C$ where an arbitrary pair of $Q_i$ have common elements, $Q$ is called a quorum.
- majority quorum $[1]$, grid quorum $[2]$, ...
- In implementation, each quorum corresponds to a multicast group.
- Length of critical path = 2

Server Cluster Hierarchy

• Each server will receive one report from each of $|N|/|C|$ hosts, and receive $f$ reports from $< r(|Q|-1)$ servers ($r$: # of quorums a server belongs to)

• Reduce the number of incoming traffic at each server by partitioning each quorum into smaller quorums

• Server traffic load = $|N|/|C| + 2^k r (|C| q^k - 1)$
  ($q$: quorum ratio = $|Q|/|C|$)
Traffic Load on Server

- Majority Quorum
- N: # of avatars; cluster optimized for single-level partition
Traffic Load on Server

- Grid Quorum
- N: # of avatars; cluster optimized for single-level partition
Putting Everything Together

• In a virtual world app, each host runs an avatar program; each avatar distributes message in three ways:
  • the zone multicast
  • five of his nearest peer’s private multicasts
  • send to a highly-connected server cluster

• Scale the size of cluster and the way to structure quorums, handle dynamic objects
Concluding Remarks

- Networked virtual worlds have many applications

- In a virtual world where there are many dynamic objects, hard to receive constant update from each object

- In our network architecture, we overcome the challenge by incorporating multicasting and information gossiping, and by reducing the length of critical path in information propagation using cluster of highly-connected servers