Proximal Workspace and VNC

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  - Server Push
  - Client Pull
  - Virtual Network Computing
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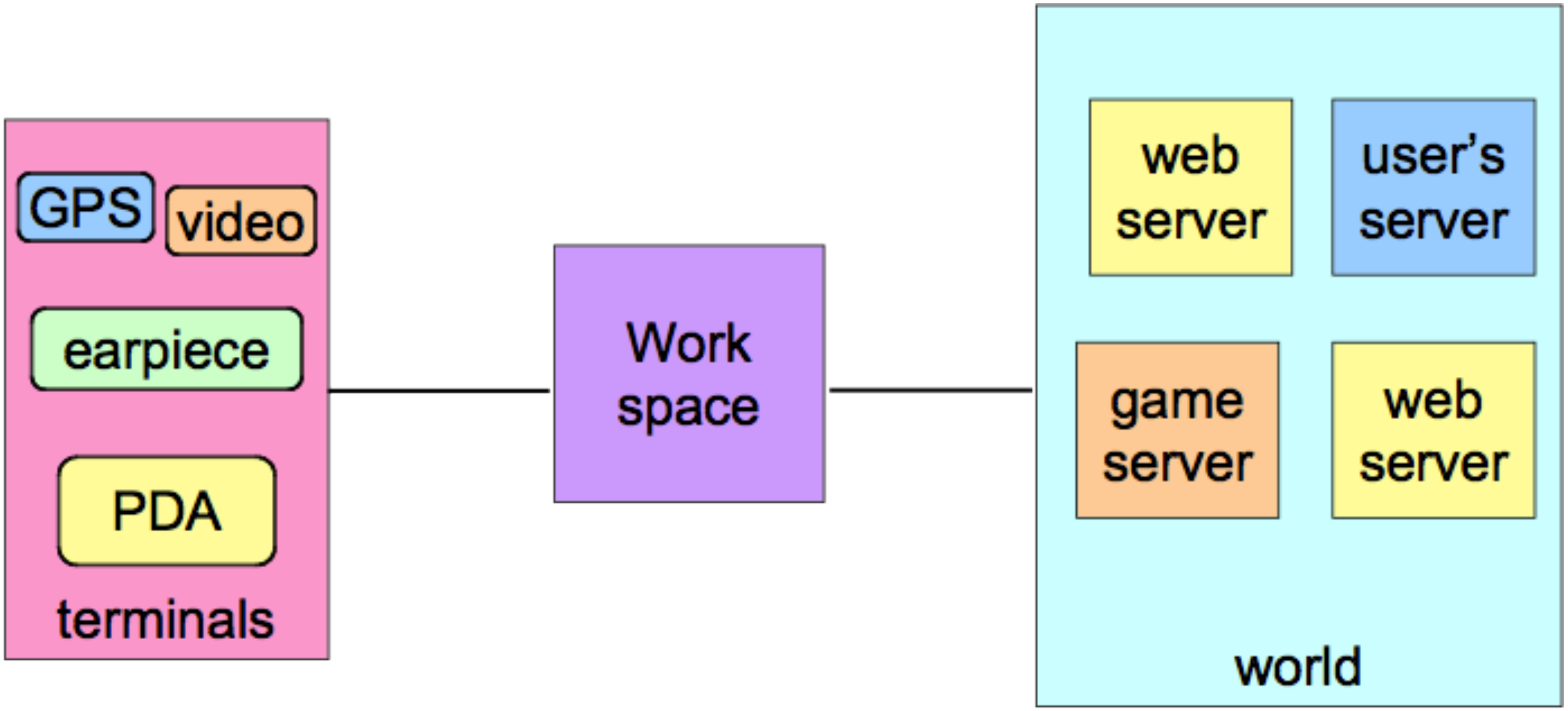
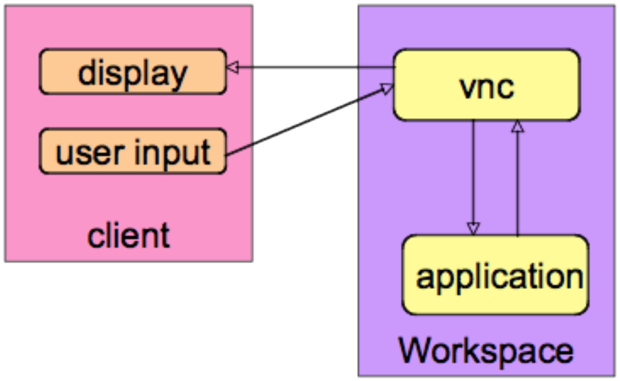
- Experimental Design & Results
- Conclusion

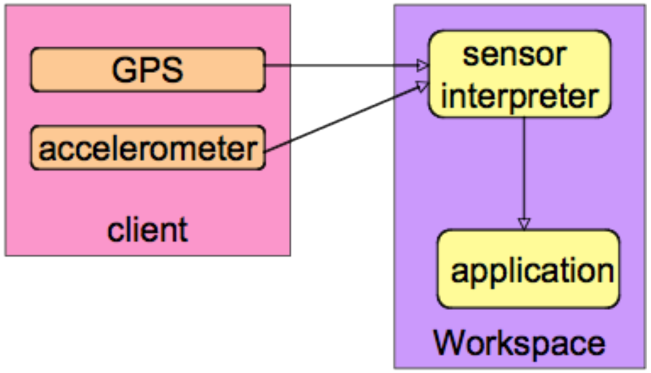
Workspace Architecture



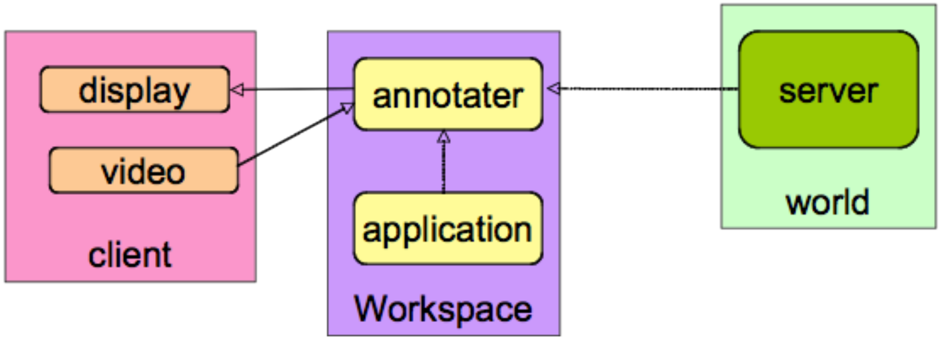
Workspace Utilities



Display Forwarding



Sensor Input

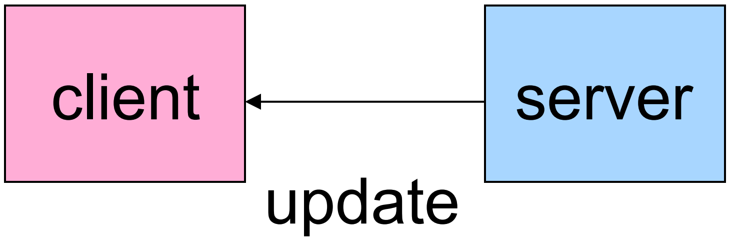


Video Annotation

The Problem with Supporting Video

- Video is hard for Thin Client Systems
  - Frequent updates
  - Many pixel changes per update
  - All server generated
  - Becomes drastically worse over high latency

Server Push

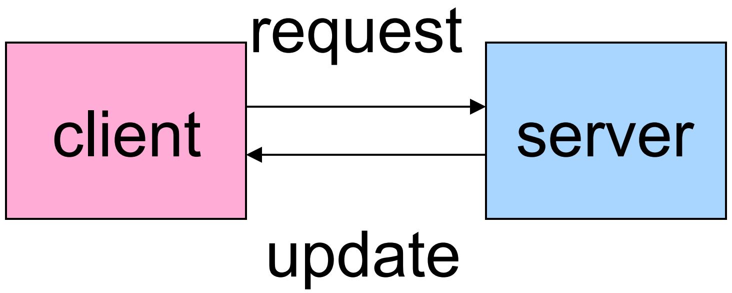


Server Push

- X-Windows is a server push system

Robert W. Scheifler and Jim Gettys. The x window system. ACM Trans. Graph., 5(2):79-109, 1986.

Client-Pull



Client Pull

- VNC is a client-pull system.

T. Richardson, Q. Stafford-Fraser, K.R. Wood, and A Hopper. Virtual network computing. Internet Computing, 2(1):33-38, 1998.

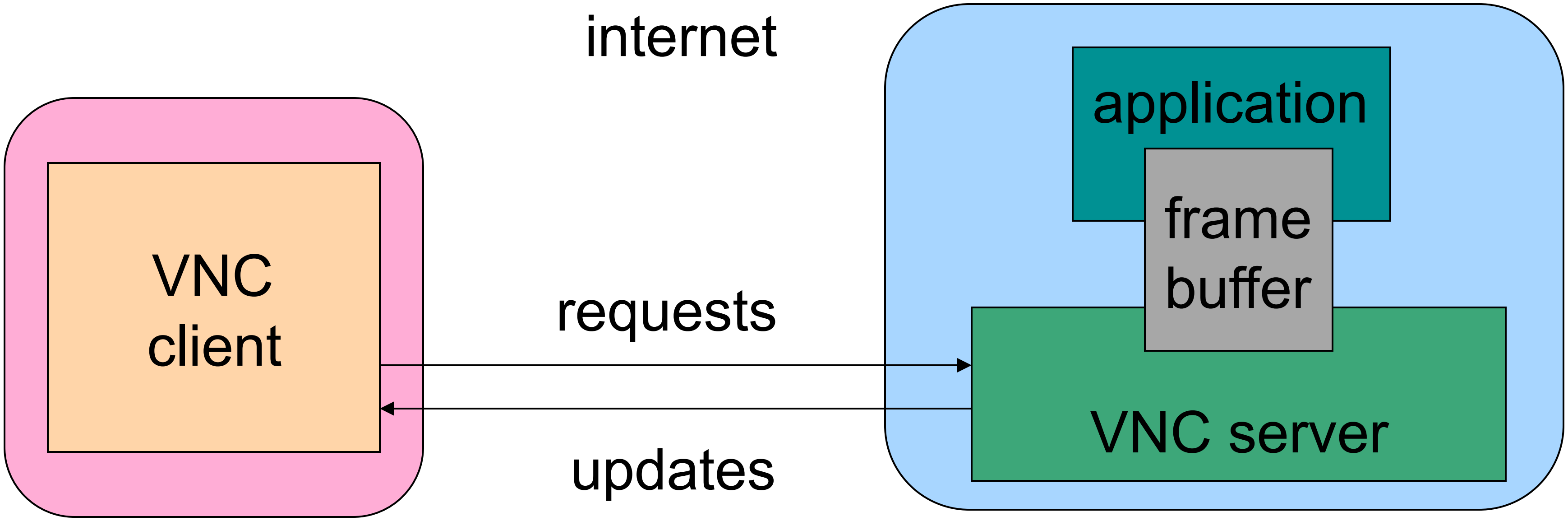
Virtual Network Computing

- VNC is a widely-used thin client system.
- It is cross-platform and has several available open-source implementations.
- It was developed by Tristan Richardson at the Olivetti Research Lab.

T. Richardson, Q. Stafford-Fraser, K.R. Wood, and A Hopper. Virtual network computing. Internet Computing, 2(1):33-38, 1998.

Tristan Richardson. The RFB Protocol. Technical report, RealVNC Ltd, 2007.

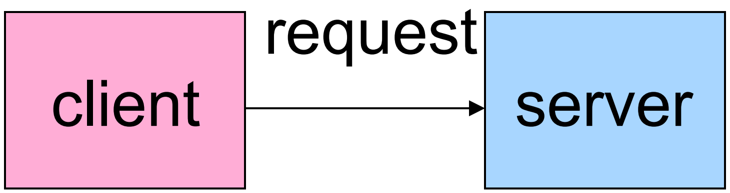
How VNC Works



- It runs at the application layer and reads updates from the framebuffer.

Defining Performance

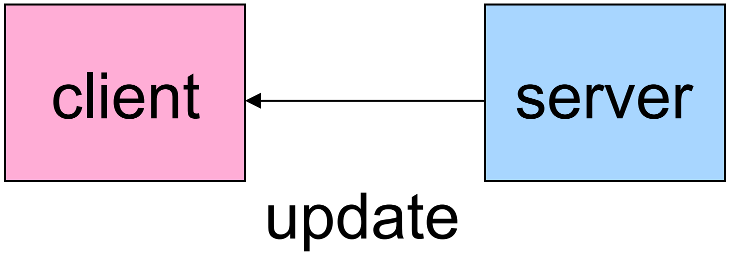
1. Client requests new update



2. Client waits

client
server

3. Server sends update



4. Client processes update

client
server

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- Adding a Message Accelerator
  - VNC with High Network Latency
  - The Message Accelerator and VNC
  - Pipelining Updates
  - Message Accelerator with High Network Latency
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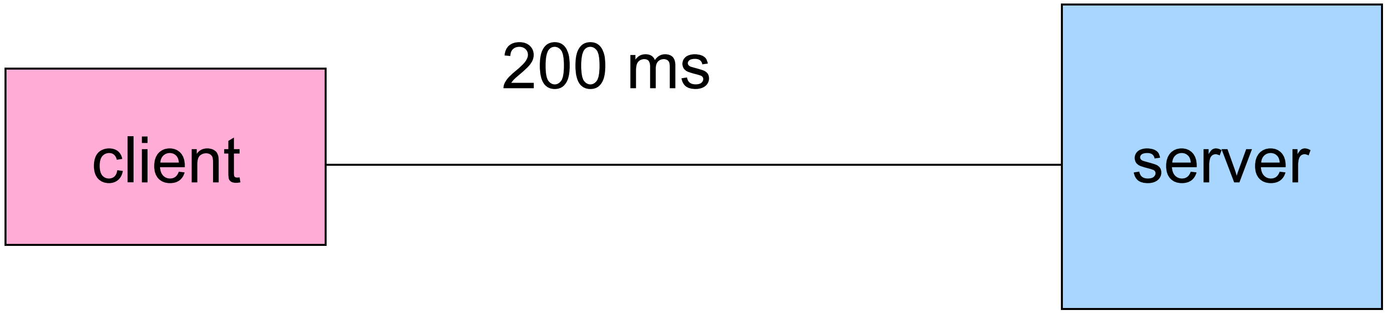
VNC with High Network Latency



- Client sends request - 200 ms
- Server sends update - 200 ms

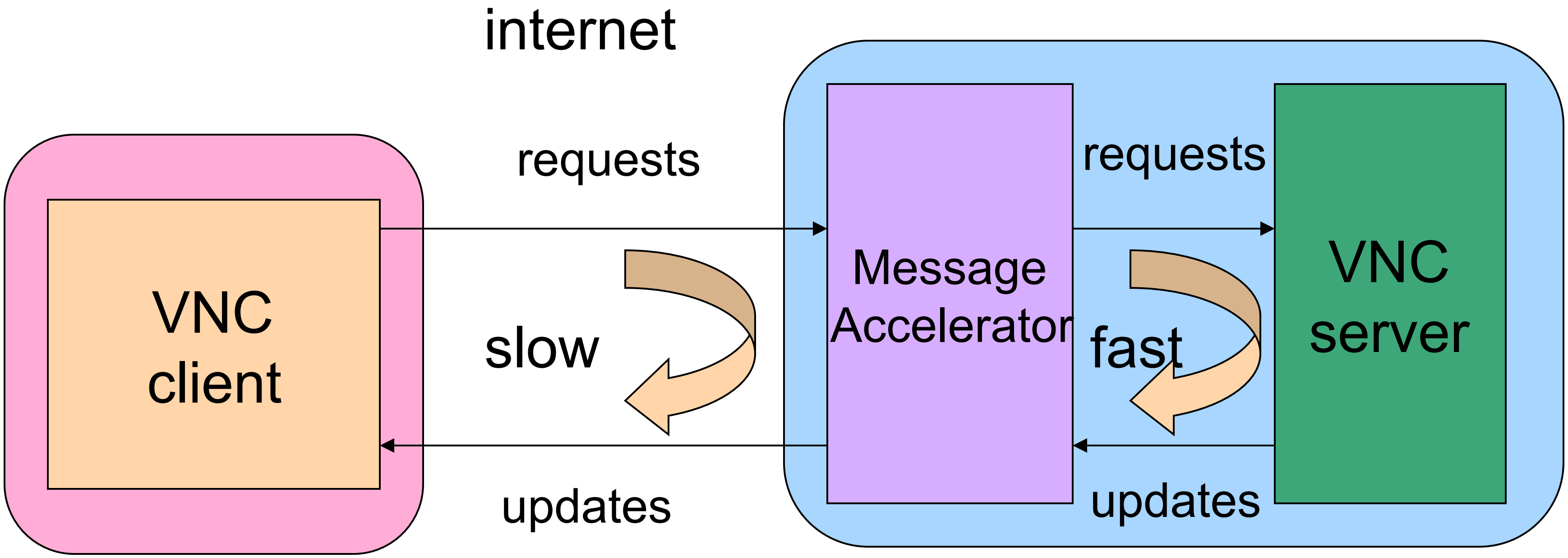
Update Rate = 2.5 updates/second

More Generally, Update Rate = 1/RTT

Two Approaches

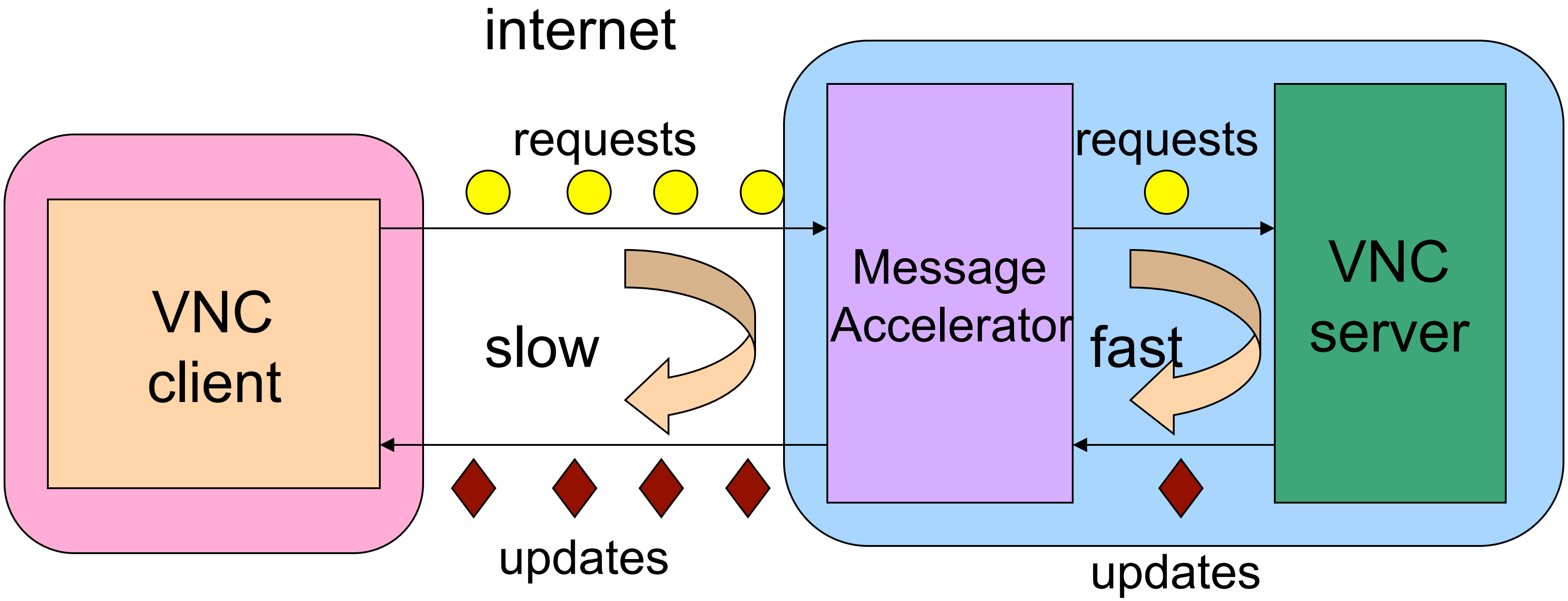
- Adding a proxy, unmodified client and server
- Modify the client

The Message Accelerator and VNC



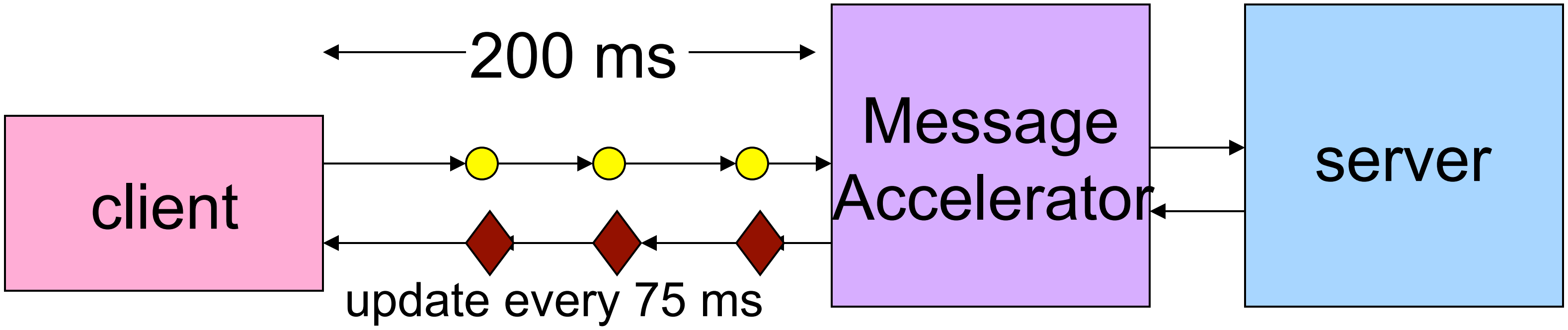
- The Message Accelerator sends requests to the server at the rate the client is processing them, and quickly receives updates from the server.
- This lets the Message Accelerator adjust for latency between the client and server

Pipelining Updates



- The proxy sends requests to the client at the rate the client is processing, without waiting for a request.

Message Accelerator - High Network Latency



- Client reads pipelined update from proxy - 75 ms

Update Rate = 13 updates/sec

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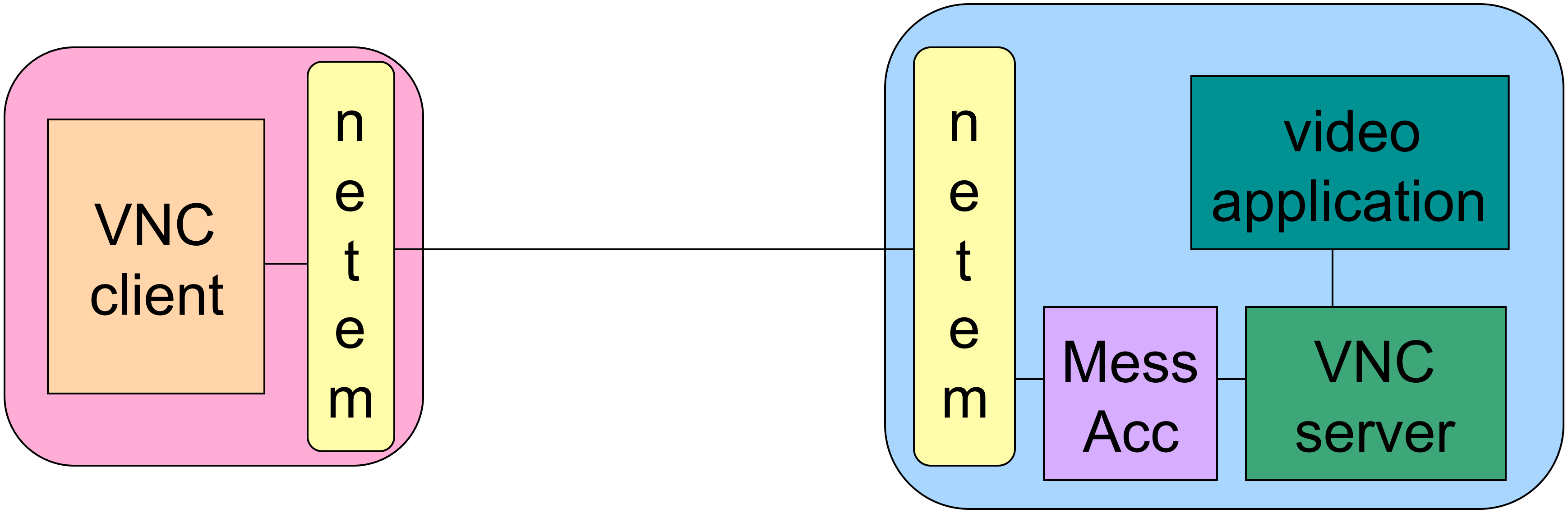
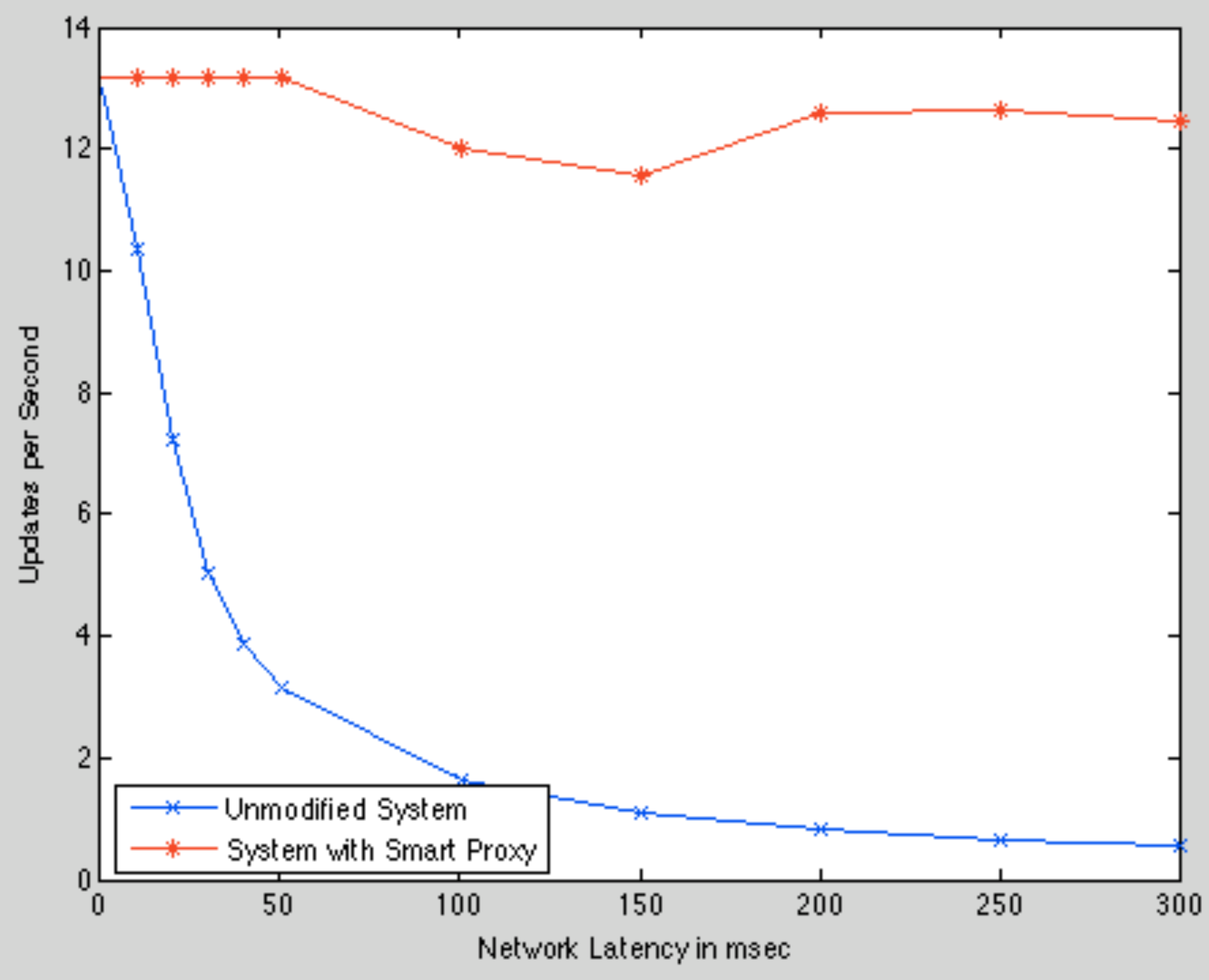
Experimental Design



- We use NetEm to add network delays to both client and server to simulate network latency

Results: Message Accelerator Outperforms Unmodified System



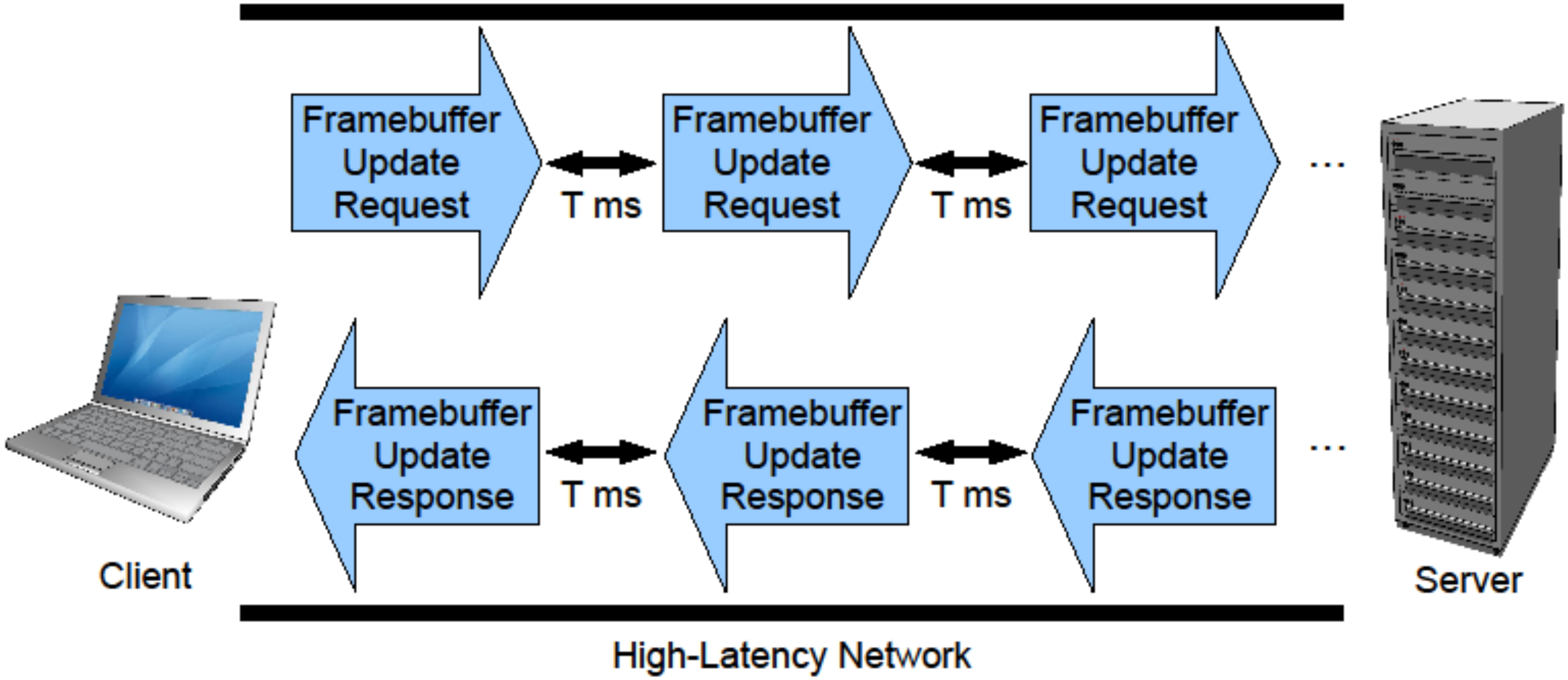
Modify the Client (Taurin Tan-atichat)

- Goal: Have a request arrive just after the frame buffer (at server) is updated
- Have client send pre-requests
  - too many requests could overload network or server
  - too few results in suboptimal performance

Our Approach: VNC-HL

- Send a pre-request periodically
  - PRP is pre-request period
- Client: upon receiving an update and processing it (including rendering), send a request and set timer to PRP
- If timer expires, send another request (and set timer)
- If update is received, process/render, and then send request and reset timer

Pipelining of Requests


Framebuffer Update Request
T ms
Framebuffer Update Request
T ms
Framebuffer Update Request
…
Client
Framebuffer Update Response
T ms
Framebuffer Update Response
T ms
Framebuffer Update Response
…
Server
High-Latency Network

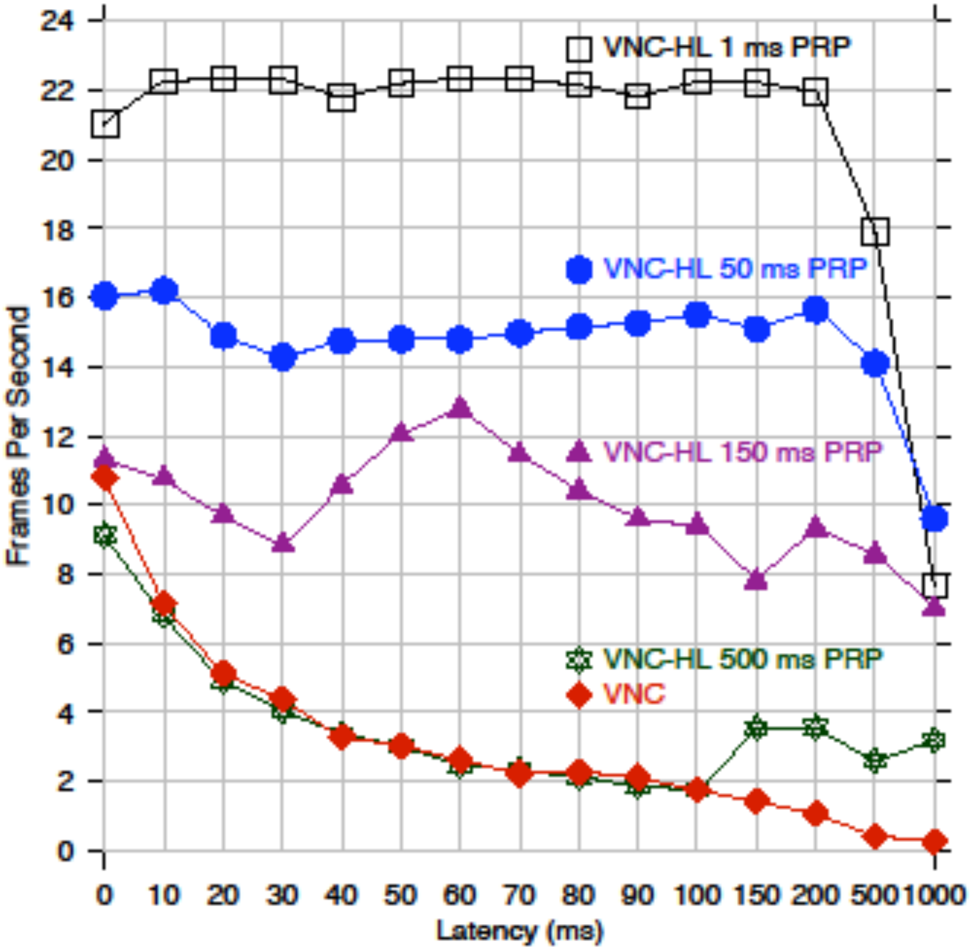
Goal

- Reach a steady state where enough frame buffer requests have been injected into the system that not many more additional requests are needed

Implementation

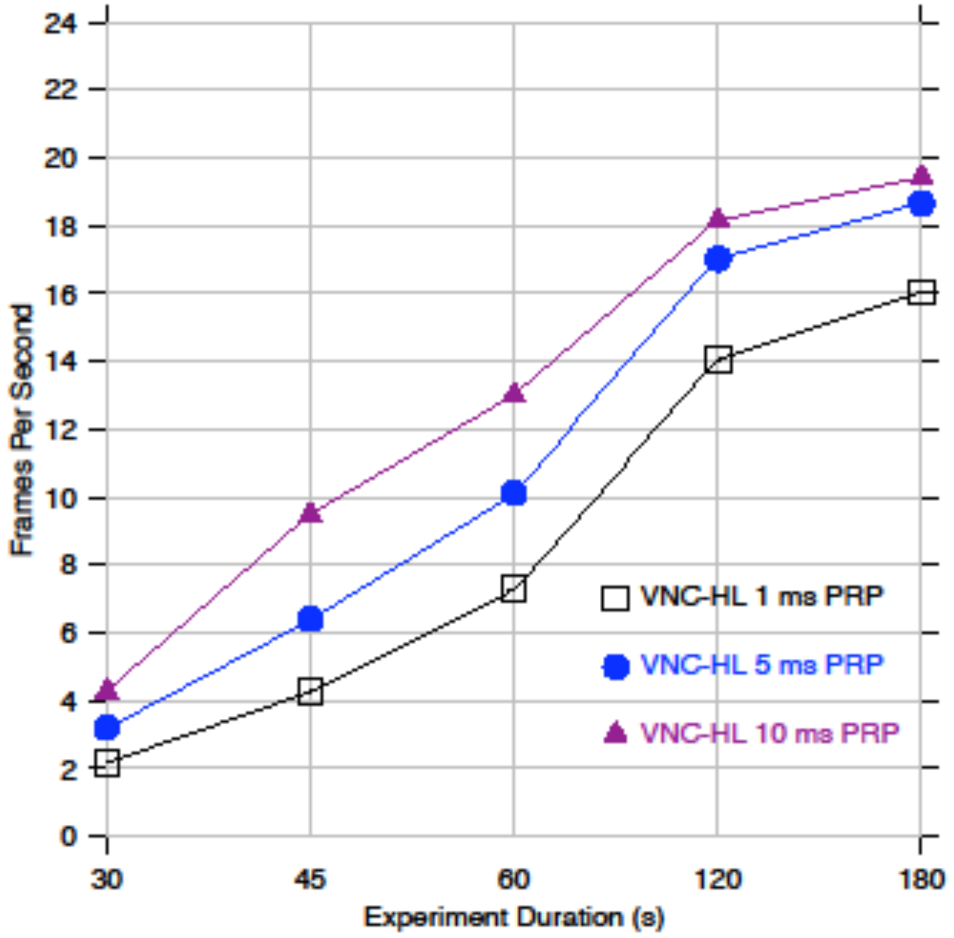
- Modified RealVNC for Unix
- Very simple change to request loop

VNC vs. VNC-HL



Frames Per Second
0
2
4
6
8
10
12
14
16
18
20
22
24
Latency (ms)
0
10
20
30
40
50
60
70
80
90
100
150
200
500
1000
□ VNC-HL 1 ms PRP
● VNC-HL 50 ms PRP
▲ VNC-HL 150 ms PRP
✡ VNC-HL 500 ms PRP
◆ VNC

FPS Improves over Time



Conclusions

- We can improve VNC performance by
  - having a Message Accelerator mediate the update rate over network latency
  - modifying the client to aggressively send pre-requests
- By using the Message Accelerator, we do not have to modify an existing code, avoiding issues of parallel code maintenance and source code availability
- In the VNC-HL approach, we achieved high performance by adding a very simple modification to the client