Remote Display

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Outline

- Remote Display Systems
- Compression
- Delivery Optimizations
- Remote 3D Display
- Measurement Techniques
- Measurement Results
- Conclusions
What is remote display?

- Applications decoupled from display
- Thin-clients:

![Diagram showing remote display](image-url)
Remote Display and Thin-client Systems

Characteristics:

➔ Division of roles and state
  ➔ Client mobility

➔ Type of protocol updates
  ➔ High-level, low-level, pixel-level

➔ Delivery of updates
  ➔ Server-driven, client-driven, user-driven

➔ Adaptive?

➔ Application support:
  – Tailored to general or specific applications
  – Transparency to applications
[Scheifler-Gettys 86]

- Client has all state
  - Inversion of client-server roles
- High-level protocol

Problems:
- No mobility [Richardson 94]
- No compression support [Danskin 94]
- Synchronization
VNC  [Richardson 98]

- Stateless client
- One pixel-level primitive
  - Multiple encodings
- Client-driven updates

Problems:
- Poor Interactivity
- No perfect encoding exists
Thin-client to the limit

The client is just an I/O interface to the underlying infrastructure
[Truman 98, Schmidt 99]

- Specialized clients
- Stateless
- No support for application execution
InfoPad [Narayanaswamy 96, Truman 98]

- Client as access and communications device
  - Wireless
  - Multimedia
- Decentralized hardware
  - “Collection of peripherals”
- Specialized interface
  - Speech and handwriting input

Problems:
- Specialized solution
SLIM/SunRay [Schmidt 99]

- Hardware-only access console
- Low-level protocol
  - Mimic client hardware
- Relaxed delivery of updates
  - UDP and own error recovery mechanisms
  - Dedicated interconnection fabric

Problems:
- Bandwidth-intensive
- Not suitable for shared networks
Rajicon [Su 02]

- Cellphones as access devices
  - Ubiquitous connectivity

- What kind of user interface?
  - Driven by constrained environment
Compression

- Must balance speed and bandwidth usage
- Tailored to characteristics of display contents
- Must be lossless
Approach

- Exploit characteristics of desktop content
  - Sharp edges
  - Solid/Patterned background elements
- Exploit repetitions in desktop content
  - Icons, window decorations, text

- Updates: HBX [Danskin 94], FABD [Gillbert 98], PWC [Ausbeck 00], TCC [Christiansen 00, 02]
- Framebuffer: TCVQ [Gillbert 00]
TCC [Christiansen 00, 02]

- Separate the details: Marks
  - Small, few colors

- Underlying components are more uniform
  - e.g. solid background regions

- Used by GoToMyPC
Delivery Optimizations

- How to improve the transmission of display data?
- Asymptotic reliable delivery [Han 96]
- Localization [Aksoy 00]
- Update dependency tracking and squashing [Gilbert 00]
Asymptotically Reliable Delivery

[Han-Messerschmitt 96]

- Too much overhead from error correction and retransmissions
- Corrupted data can be useful
  - Graphics are resilient to errors
  - Improve response time by not delaying delivery

Problems
- At odds with compression
- Applications must be aware of mechanism
Localization [Aksoy-Helal 00]

- Move functionality to the client
- Used by Citrix MetaFrame
Remote 3D Display

How to balance the thin-ness of the client with the requirements of the application?

- High resource requirements
  - Shared environment

- Approach: Partition the 3D pipeline
**Dedicated rendering server** [Stegmaier 02]

- Generic solution
- Could possibly off-load application server

**Problem**
- How to deliver the content?
Push functionality to the client [Levoy 95]

- Render high-quality and low-quality images
- Transfer only difference image
  - Improved delivery

Problem
- Not generic
- Server still doing all the work
Stream of rendering components [Humphreys 01,02]

- Divide pipeline for scalability
  - Does not address delivery issues

- Framework for balancing rendering work
  - Possibly dynamically?
Measurement Techniques

- Traditional application benchmarks not suitable
  - Only measure server performance
  - Many are throughput-based

- Cannot instrument proprietary systems
Capture application traces

[Danskin 94, Schmidt 99]

- Capture protocol messages generated in a user session

Benefits
- Realistic
- Repeatable
- Flexible

Problem
- Need open protocol
Slow-motion benchmarking
[Nieh-Yang-Novik 03]

• Use network monitoring
  – Systems are just blackboxes
  – Measure of client-perceived performance

• Introduce delays
  – Avoid merging of display updates
  – Plus: Mimics real user behavior

Problems
• Client processing not fully accounted for
• Cheating
User-perceived latency is key [Wong 00, Schmidt 99]
Network latency is key [Lai 02]
Thin-clients ideal for constrained environments (e.g. PDAs) [Lai 04]
User-perceived latency not driven by data transfer [Lai 02, 04]
Conclusions

- Many systems and many approaches
  - Not one perfect system
  - Is this even possible?
- Complex systems
  - Plenty of room for optimizations
- System response time is key
  - More important than bandwidth usage
- Open problem: Remote 3D display