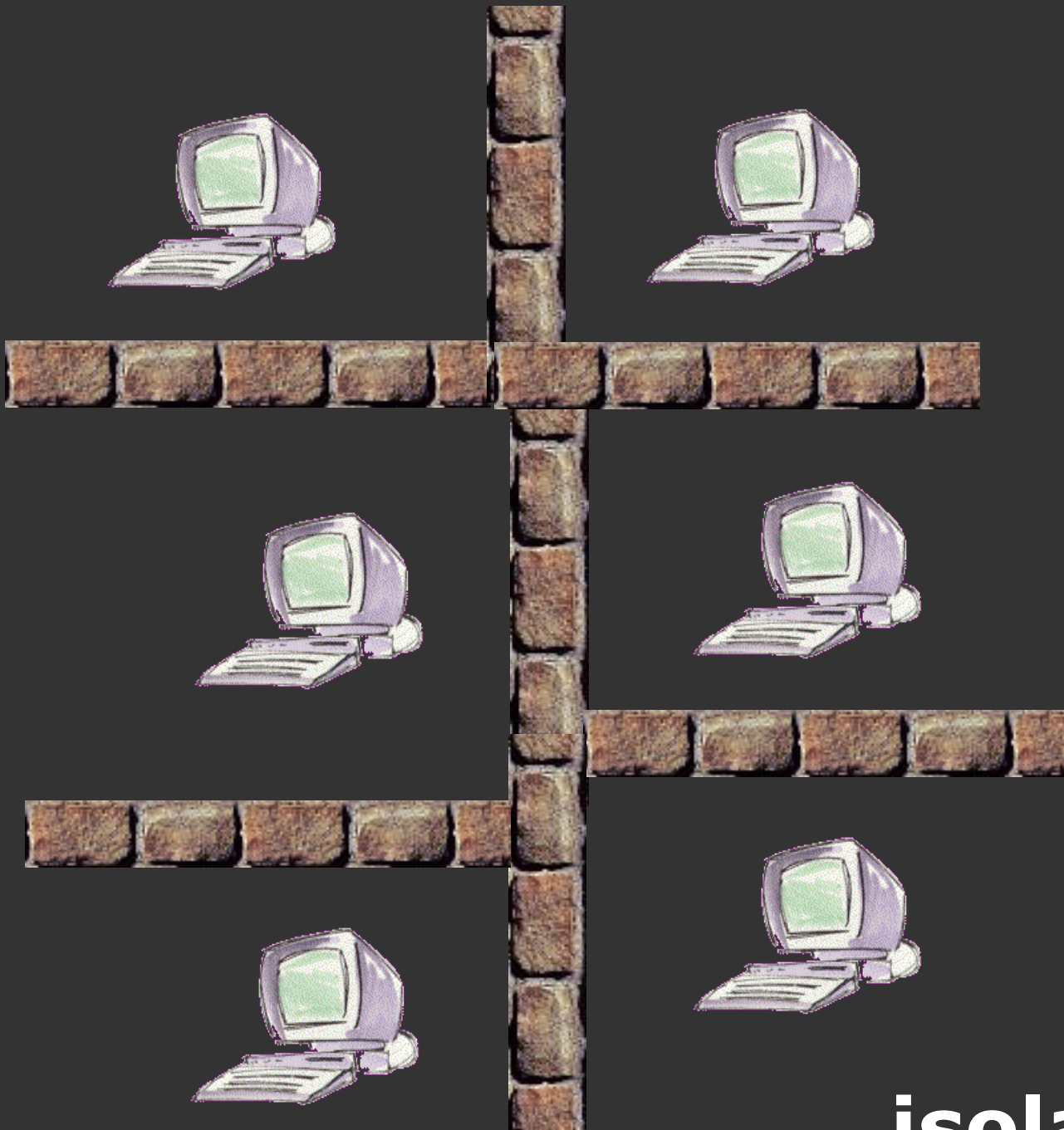


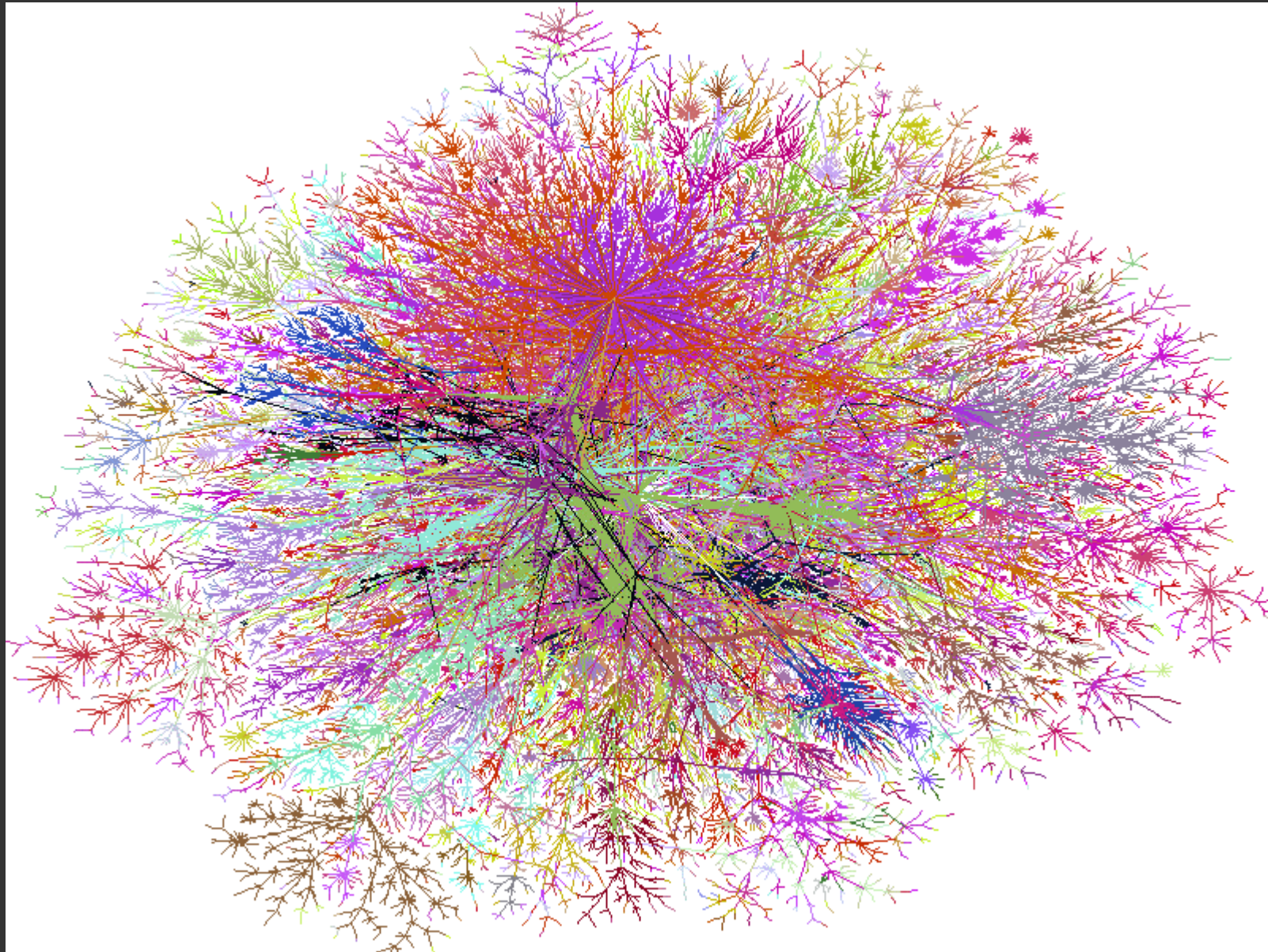
THINC: A Virtual and Remote Display Architecture for Desktop Computing

Ricardo A. Baratto
Network Computing Laboratory
Columbia University



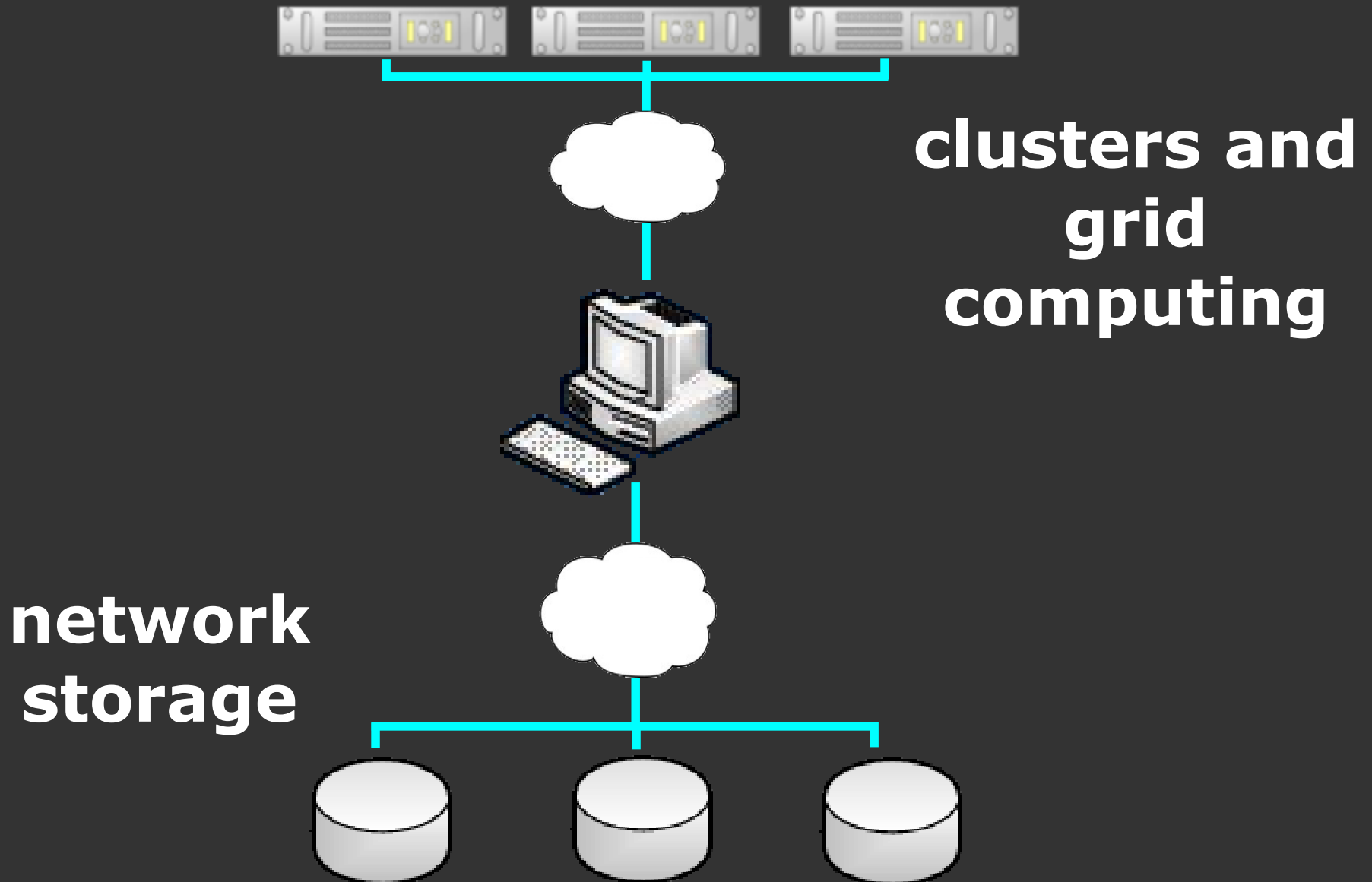
isolation...

... connectivity

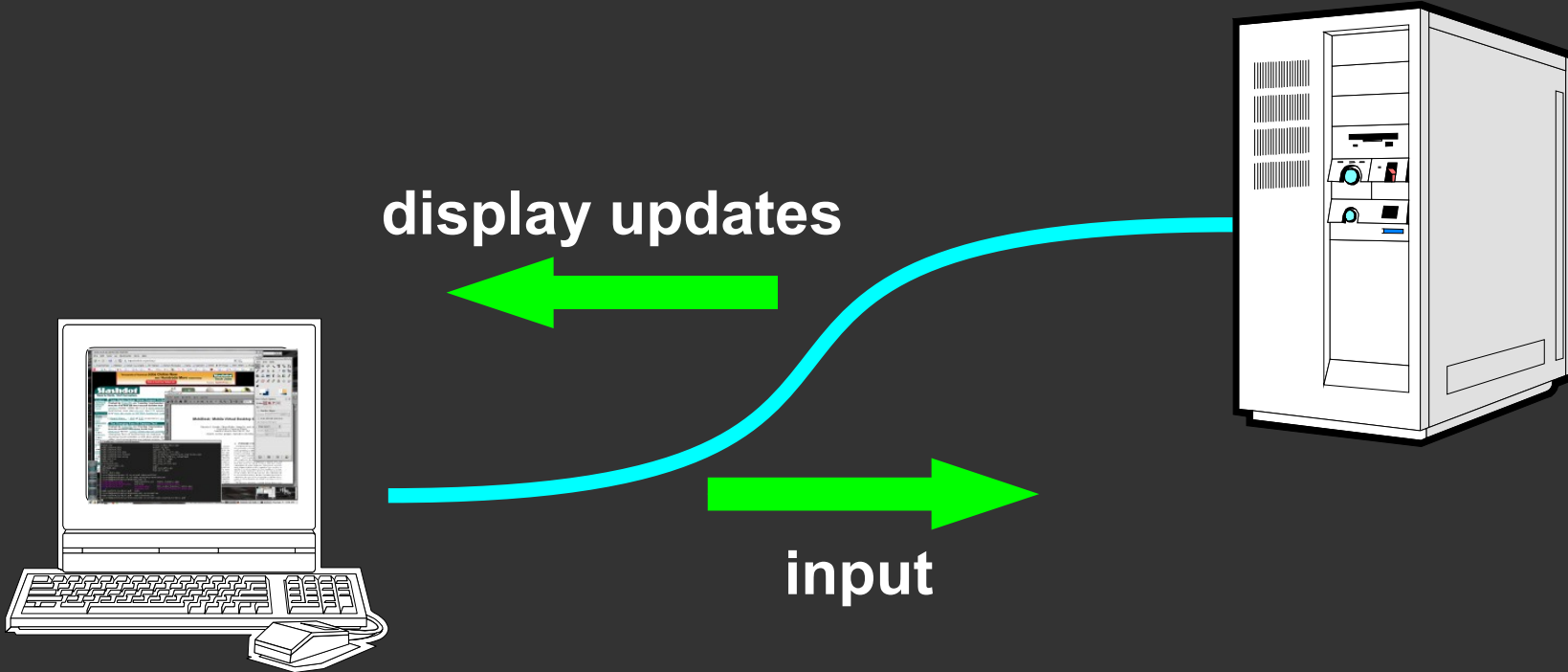


Source: Internet Mapping Project (<http://research.lumeta.com/ches/map/>)

dis-integration of the computer

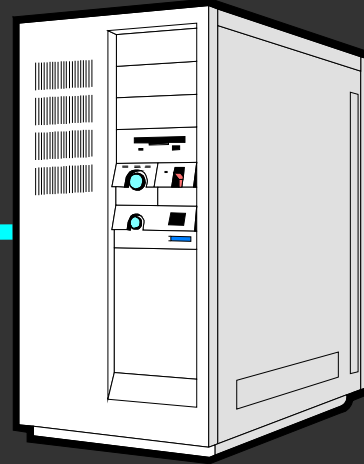


remote display

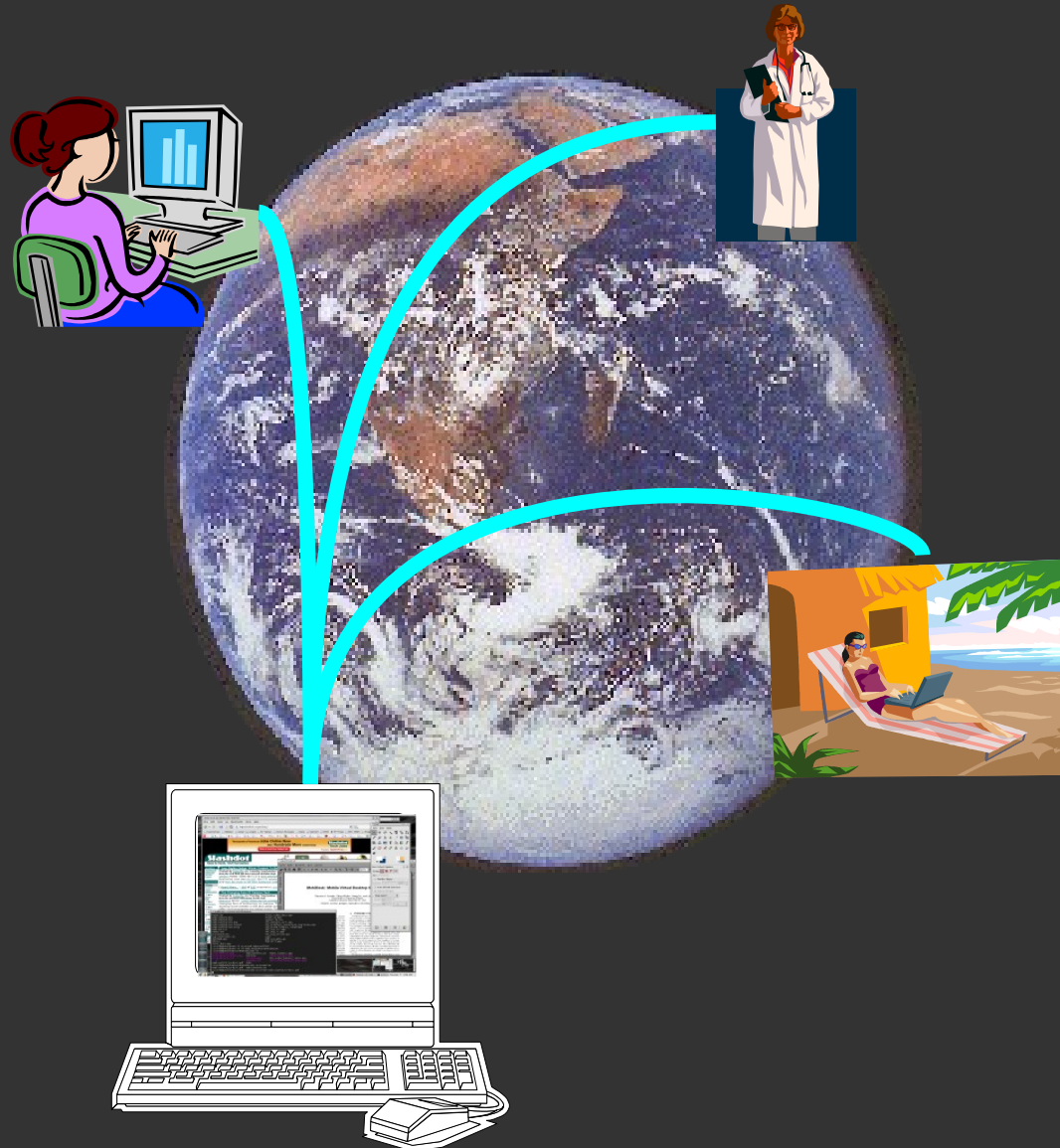


benefits

ubiquitous access



remote collaboration



online help



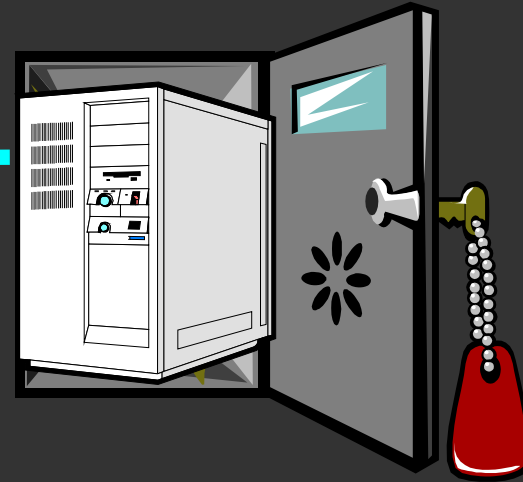
"Okay your father managed to get a mouse. Now how do we use it?"

thin clients

application processing
and data



stateless client



secure server room

existing systems

CITRIX[®]

REAL
VNC

Microsoft
Windows xp

GoToMyPC[®]

NOMACHINE
BUILDING THE NETWORK COMPUTING ON THE POWER OF X



X

what's wrong?

problem:

- focused on office applications on LAN and reducing data transfer on low bandwidth links

therefore:

- poor support for display intensive interactive applications
- poor support for higher latency WAN environments

THINC

**virtual and remote display
architecture
for desktop computing**

contributions

- high performance remote display system
[SOSP 05]
- first to natively support multimedia applications
- superior remote display support for mobile devices [WWW 06, SCC 06]

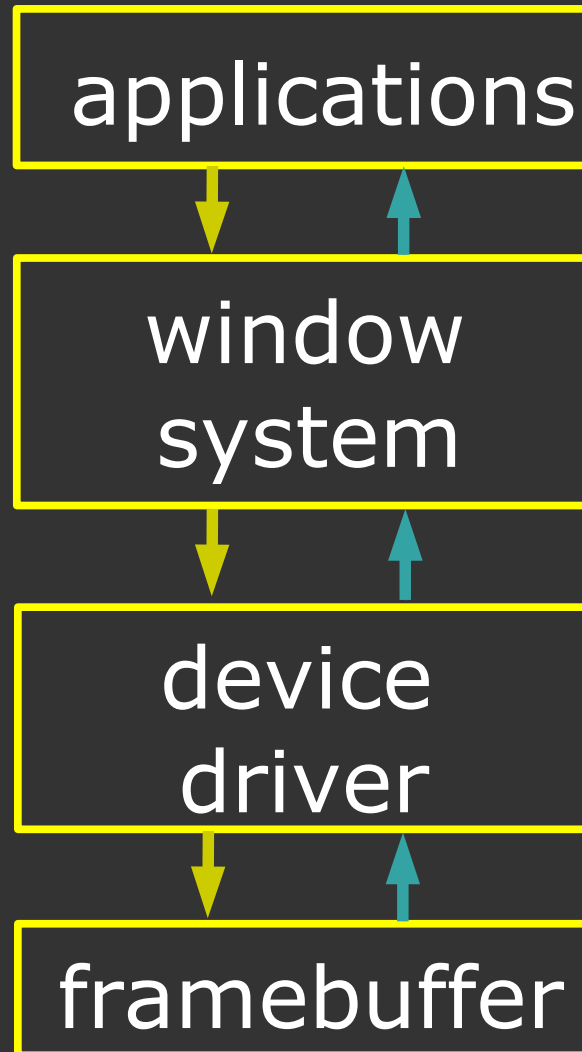
contributions II

- MobiDesk: desktop utility computing infrastructure [[MobiCom 04, best student paper award](#)]
- A²M: protect MobiDesk from DDoS attacks
- beyond remote display: desktop recording [[SOSP 07](#)]

THINC remote display

- simple display protocol
 - COPY, Solid Fill, Tile Fill, BITMAP, RAW
- focus on architecture of the system to improve performance
 - interception
 - translation
 - delivery

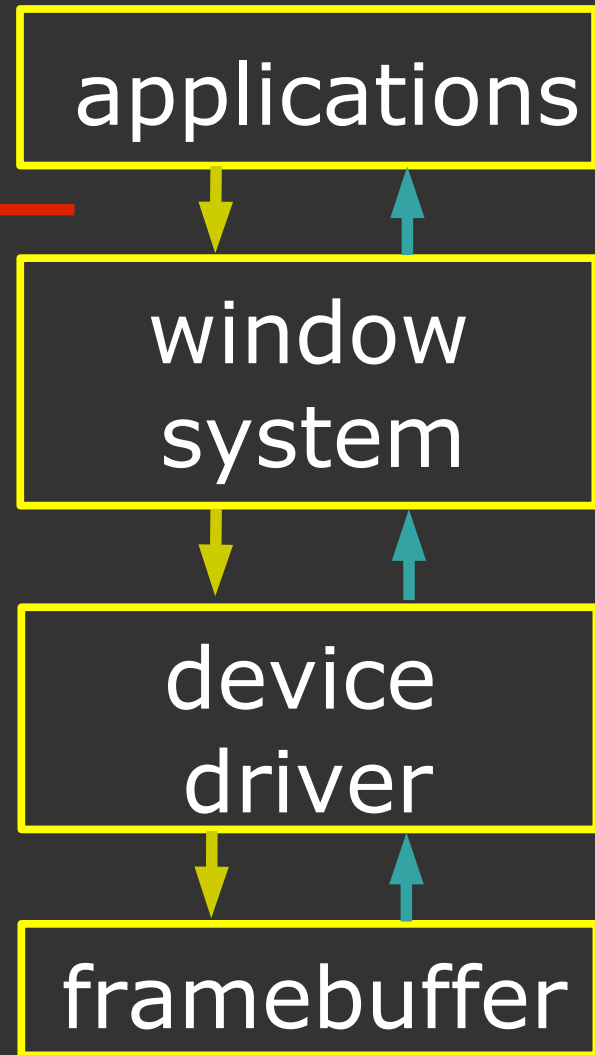
interception: traditional display pipeline



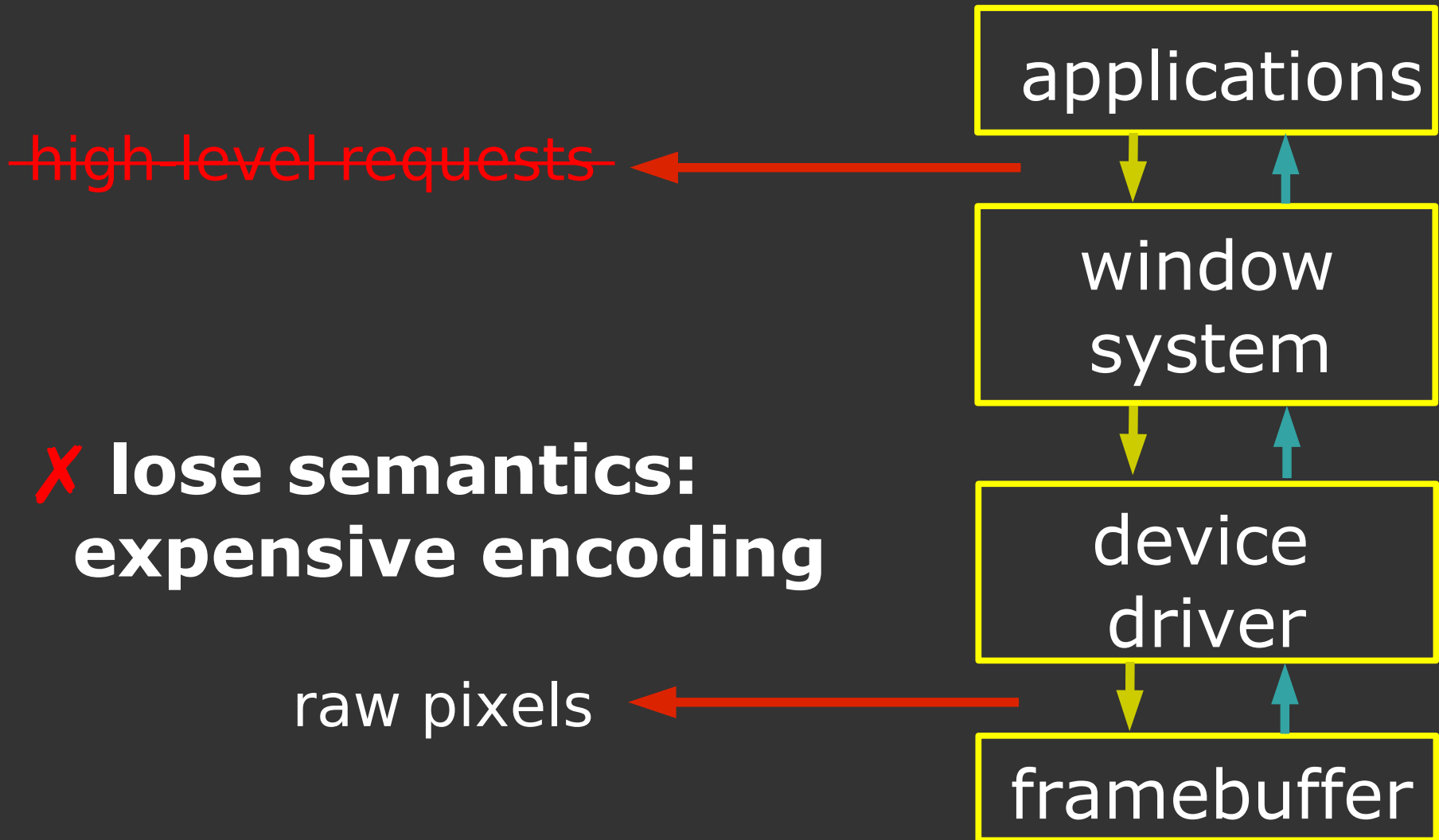
interception

high-level requests

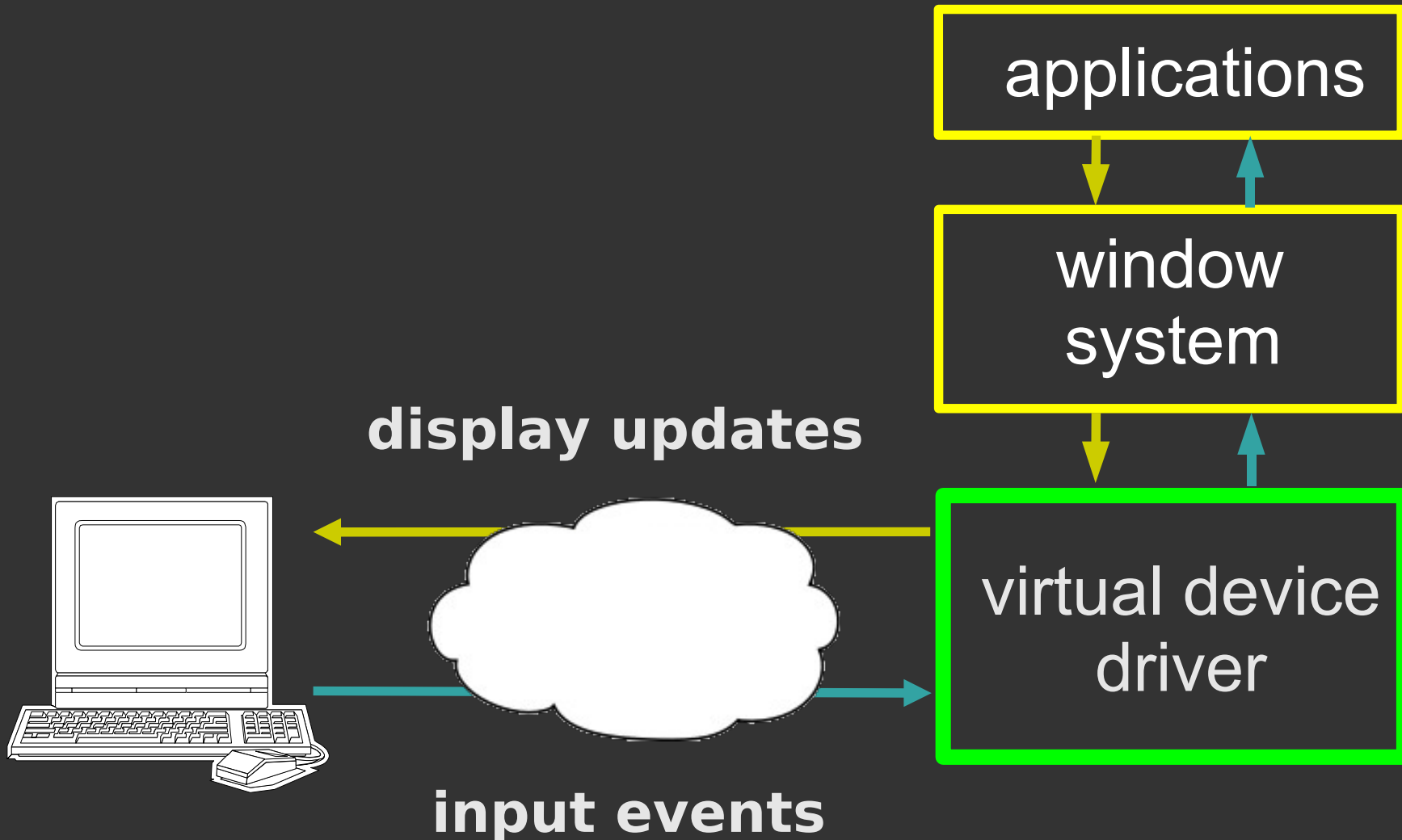
- X stateful client hurts mobility**
- X app – window system synchronization**



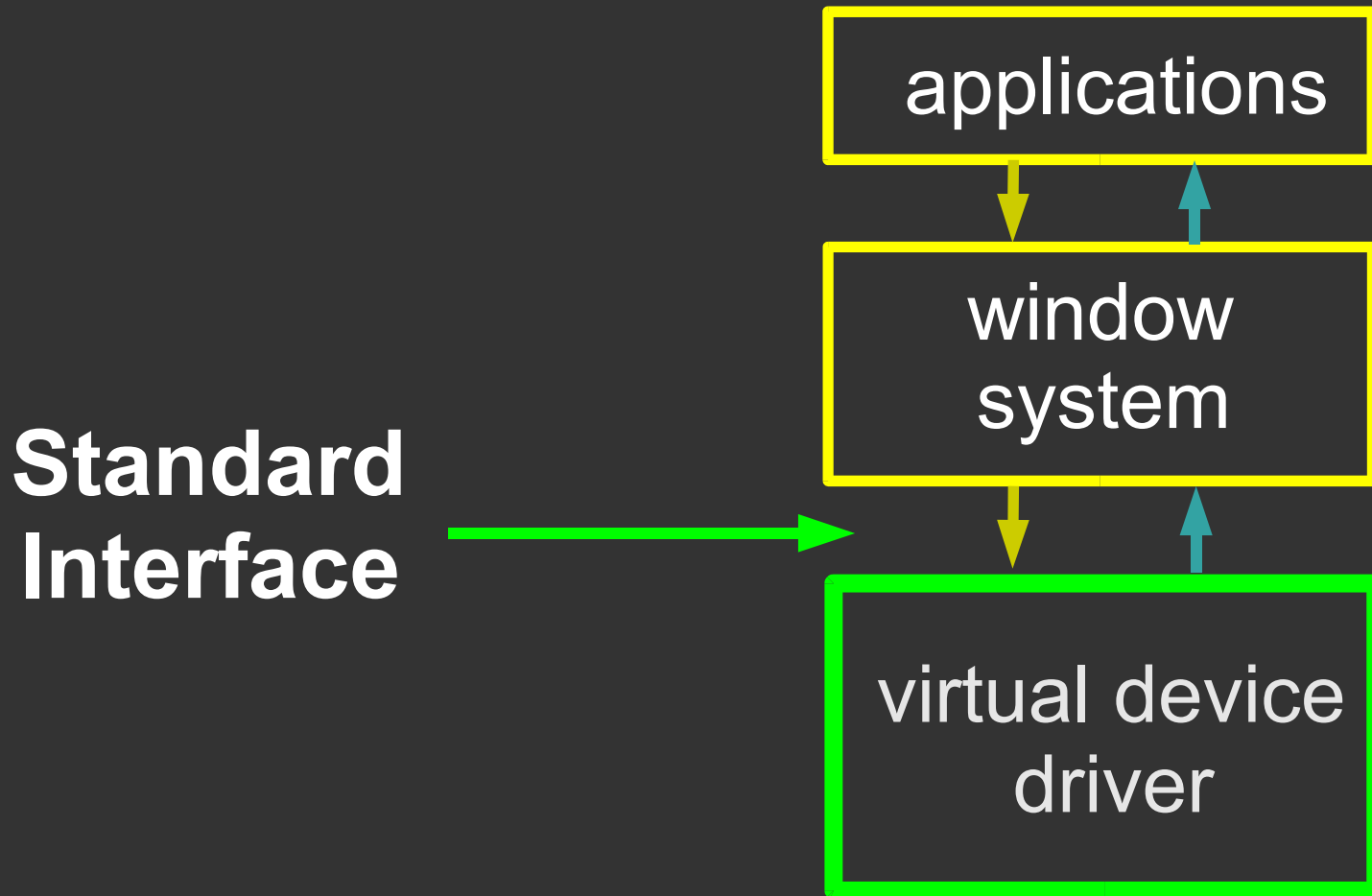
interception



virtual display architecture

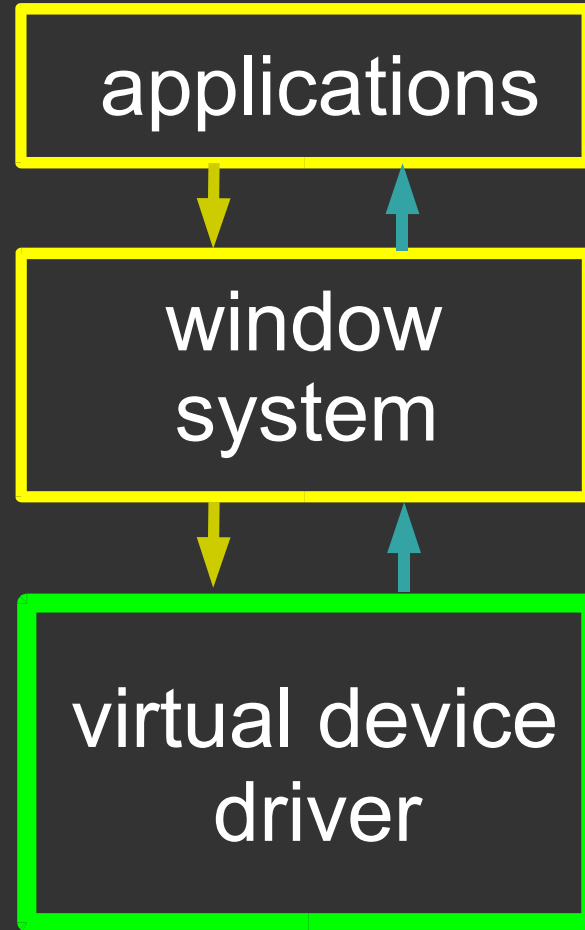


benefits



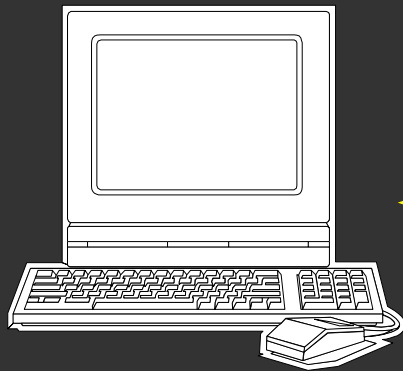
benefits

Leverage
existing
technology



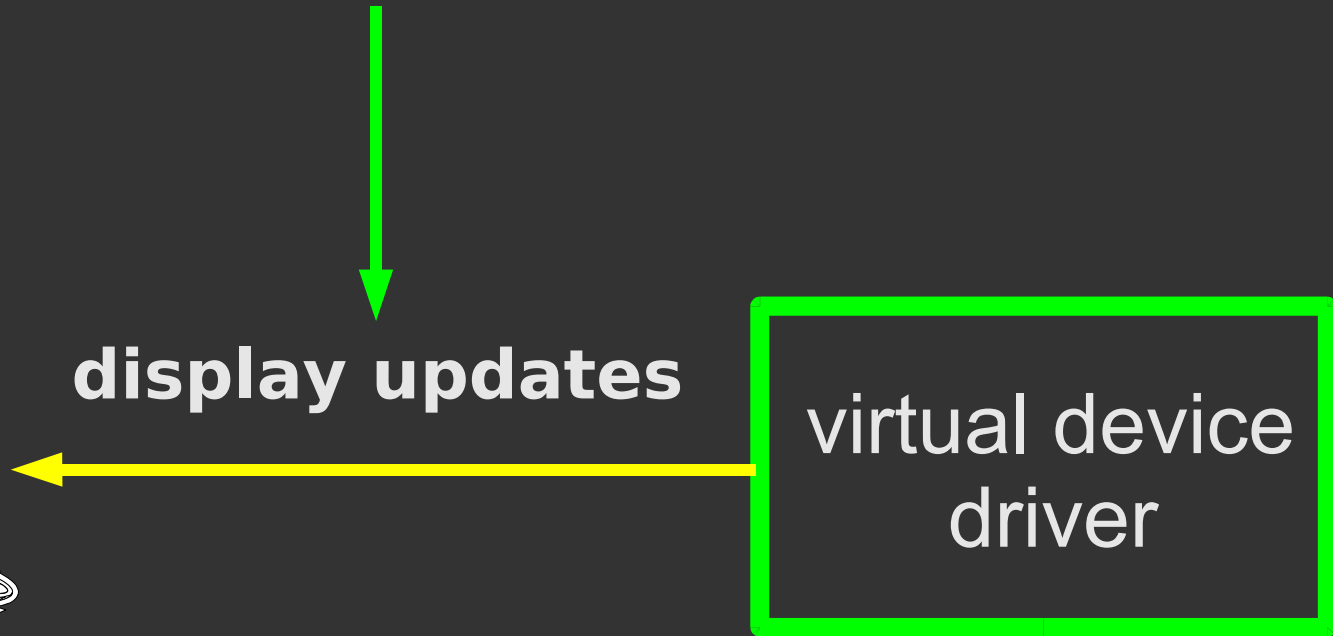
benefits

Simple, low-level
protocol



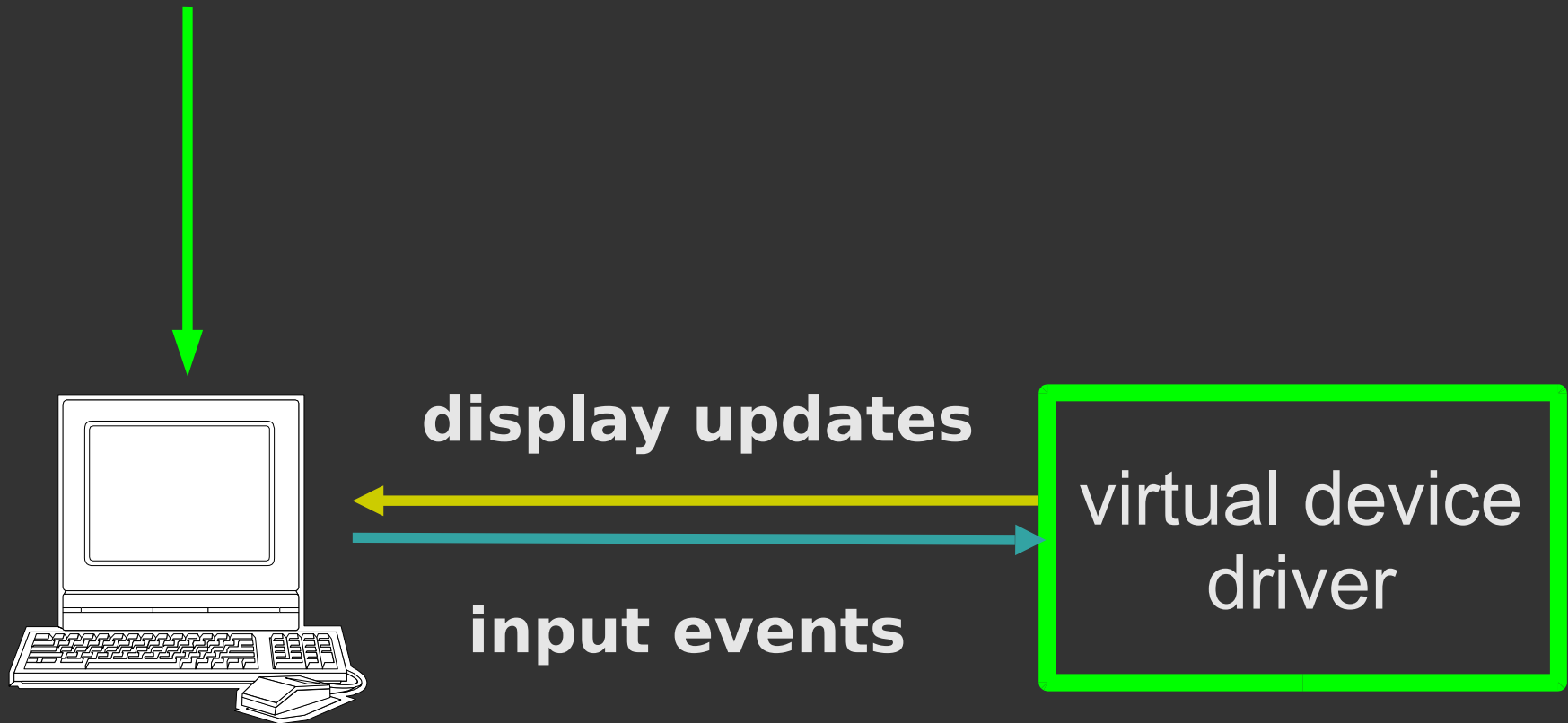
display updates

virtual device
driver



benefits

Simple, stateless
client



translation

**use and preserve semantic
information for efficient
translation**

translation

- **use semantic information when doing translation**

use request semantics to generate update

application

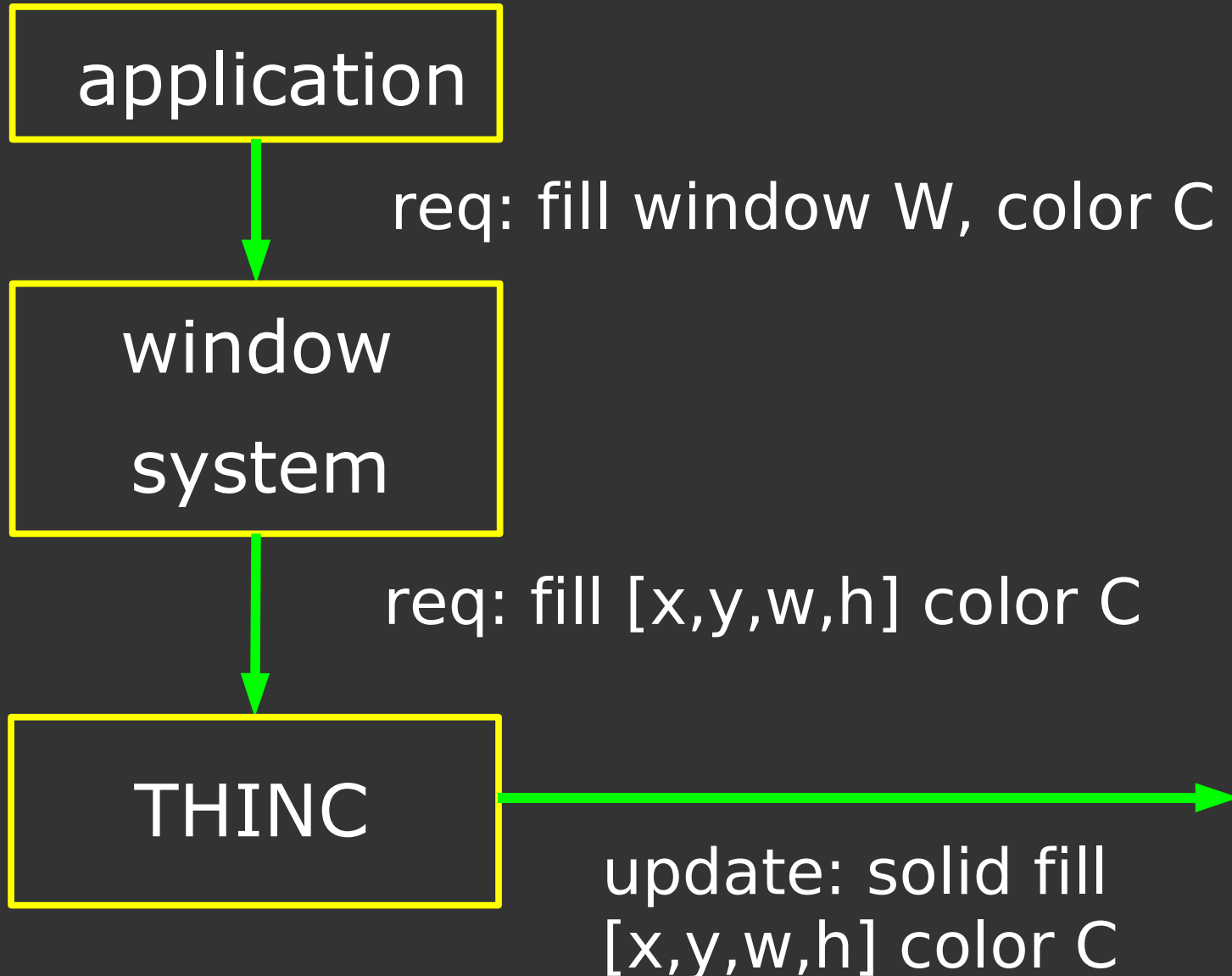
req: fill window W, color C

window
system

req: fill [x,y,w,h] color C

THINC

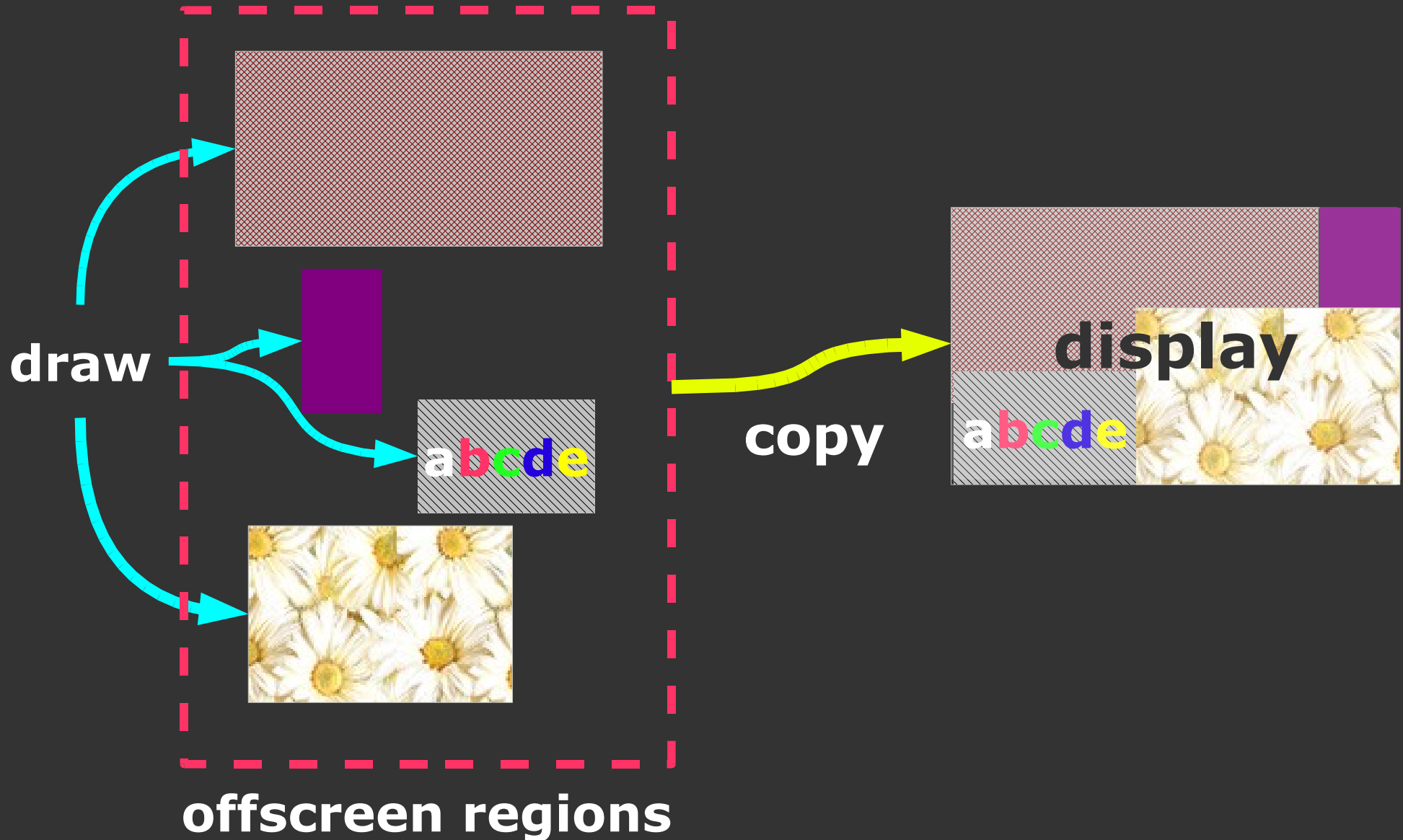
update: solid fill
[x,y,w,h] color C



translation

- ✓ **use semantic information when doing translation**
- **preserve semantic information throughout the system**

why preserve semantics: offscreen rendering



offscreen rendering (cont)



offscreen
region

command log

**merge, clip, and discard commands as
needed**

delivery

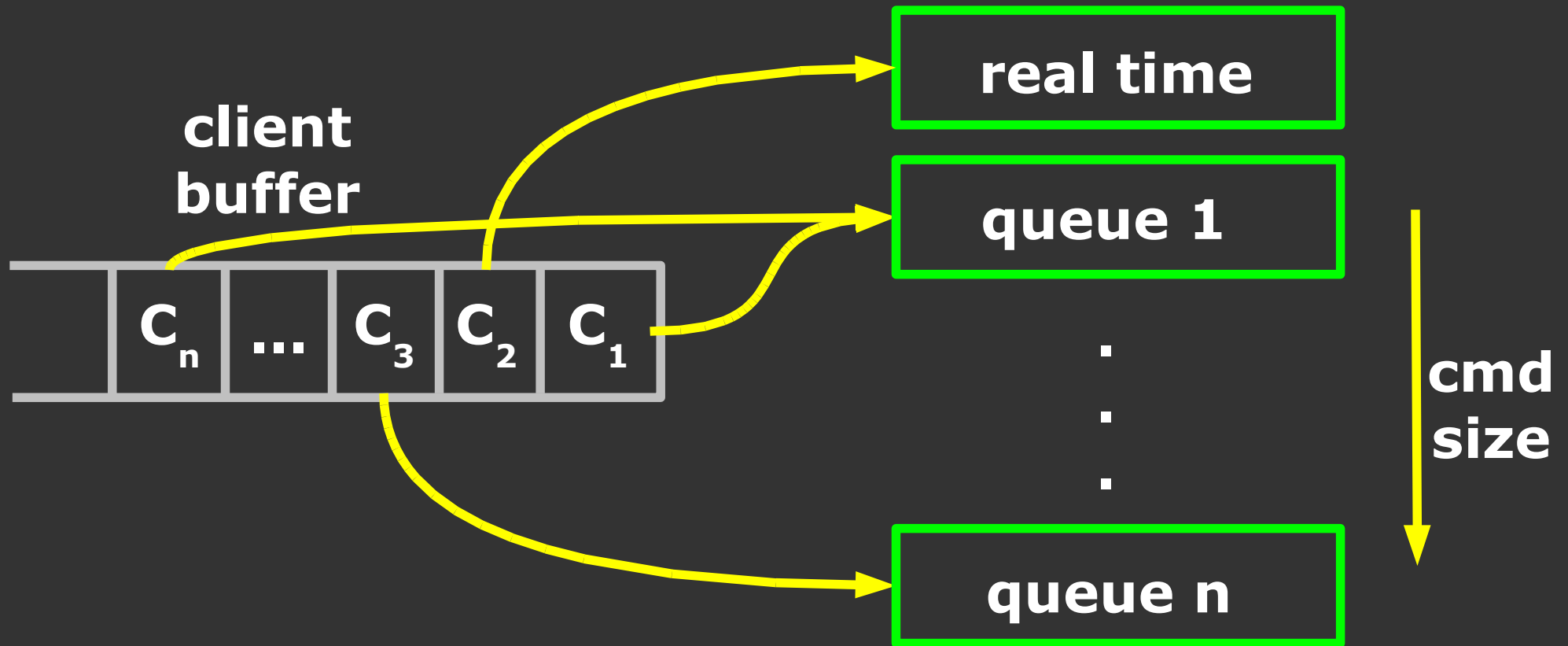
**maximize interactive
response of the system**

delivery

- transmit updates as soon as possible
- merge, clip, and discard updates as needed

... not all display content created equal

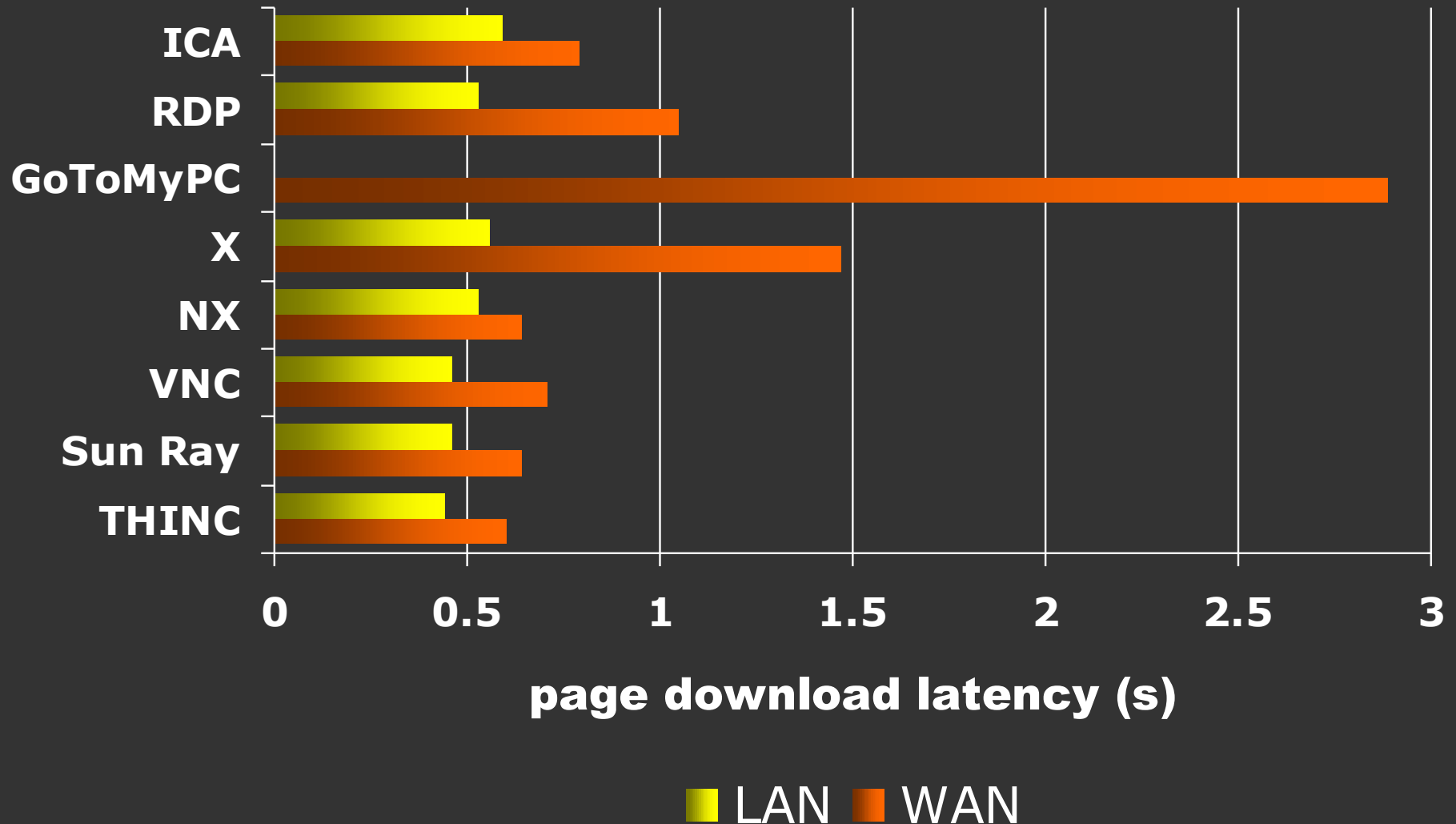
shortest remaining size first scheduler



experimental results

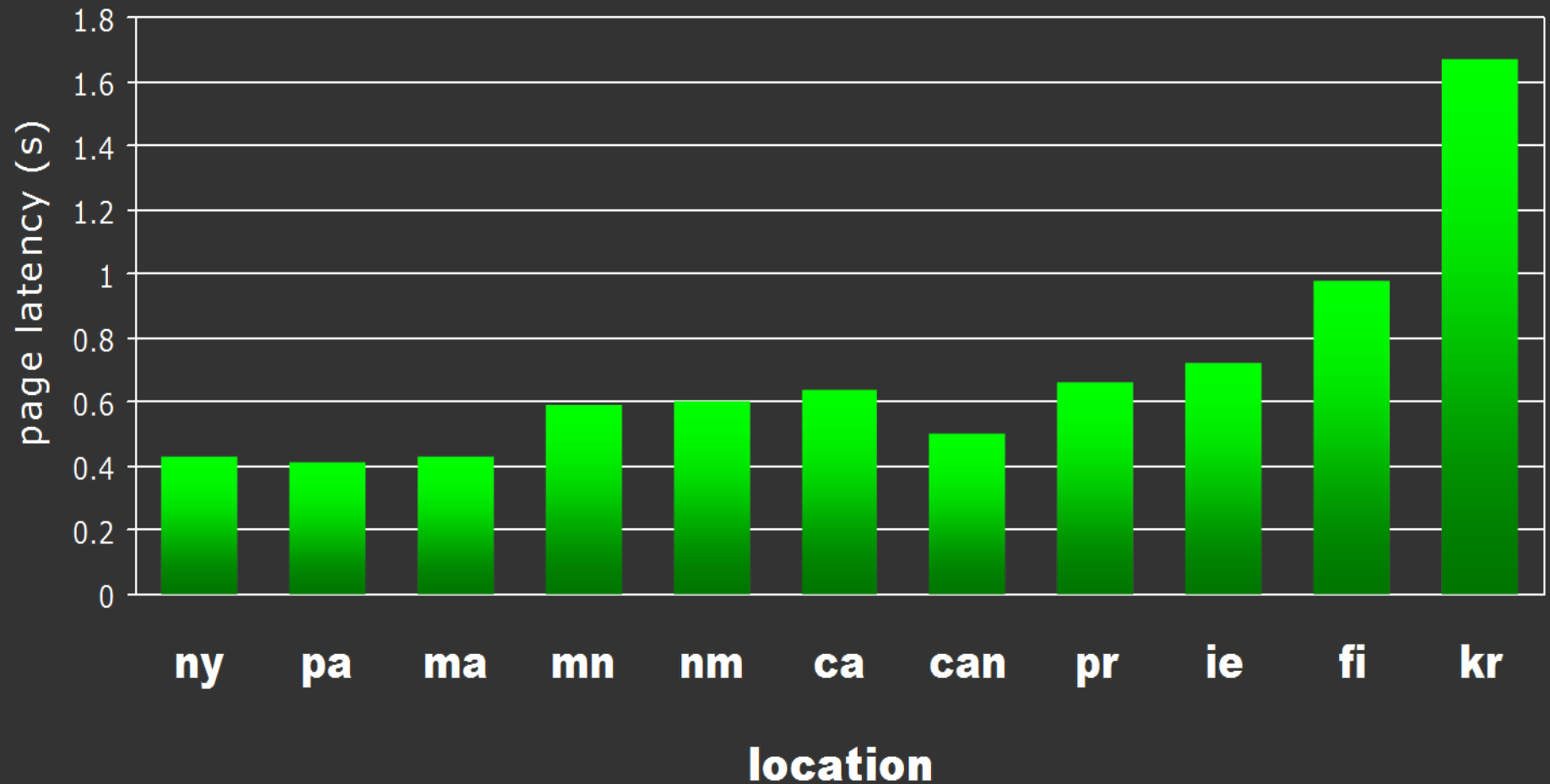
- X/Linux prototype
- web browsing performance
 - comparison to existing systems
 - performance on wide area networks

web browsing performance



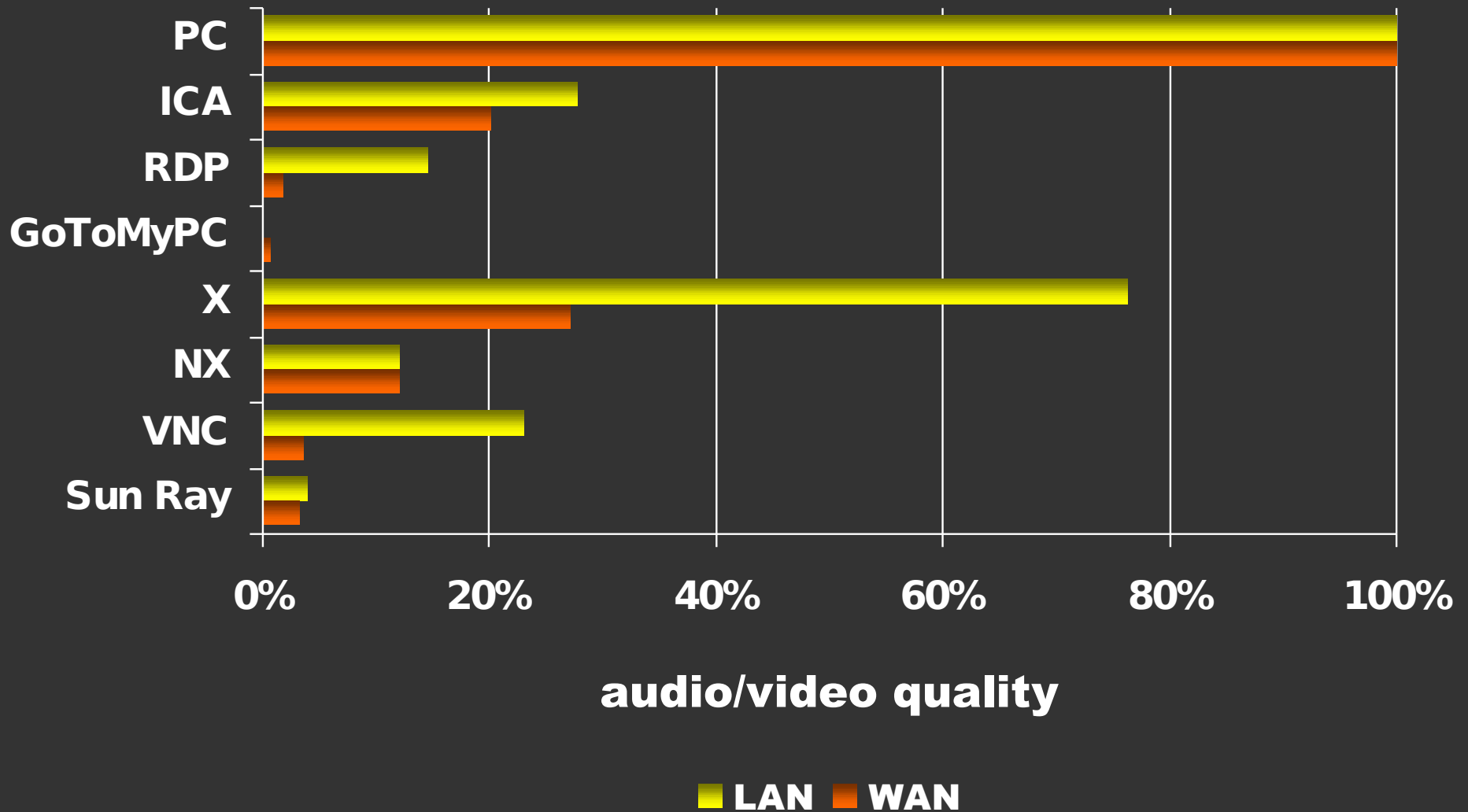
... up to 4.8 times better performance

WAN web browsing performance



multimedia

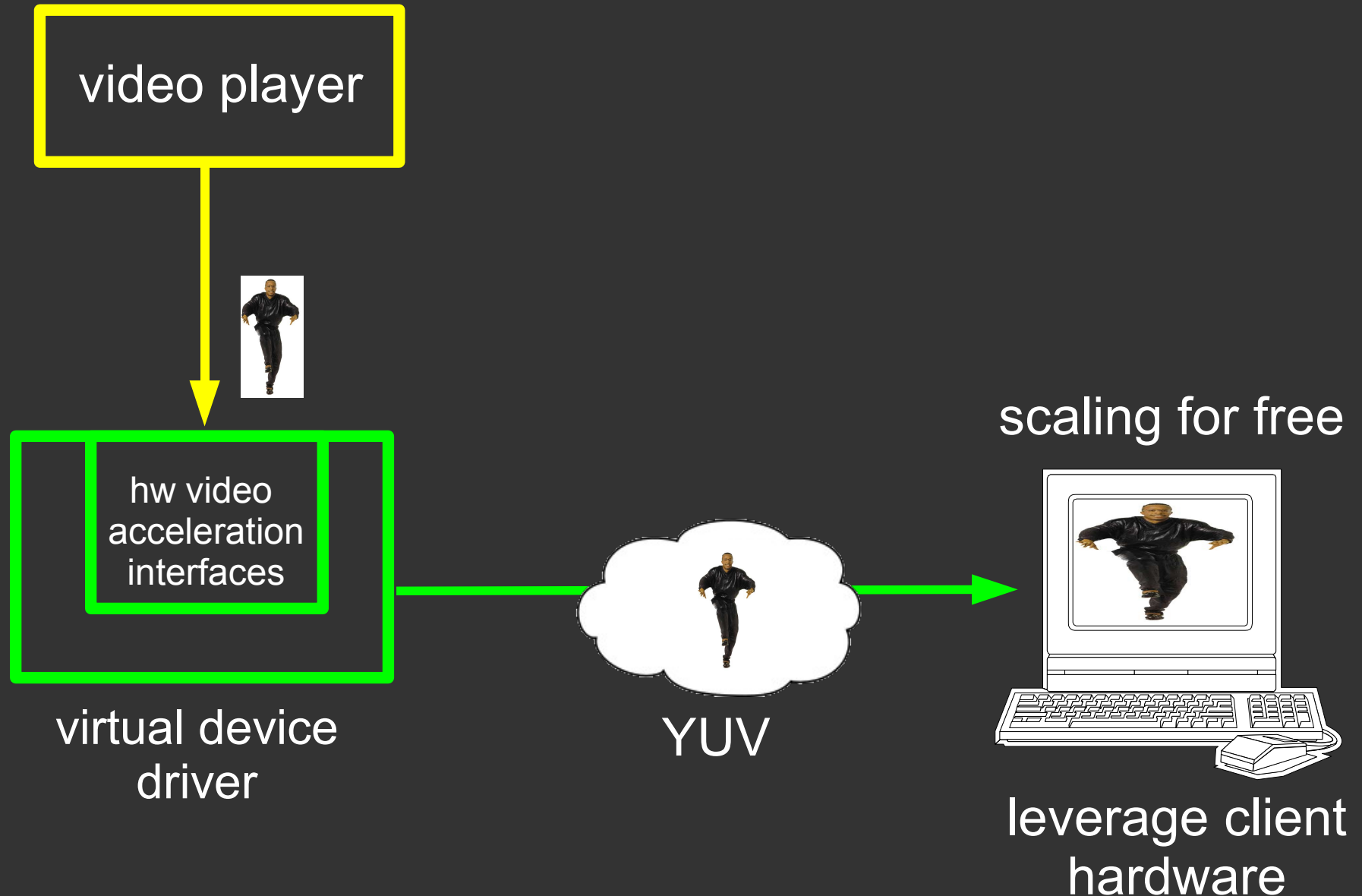
existing systems



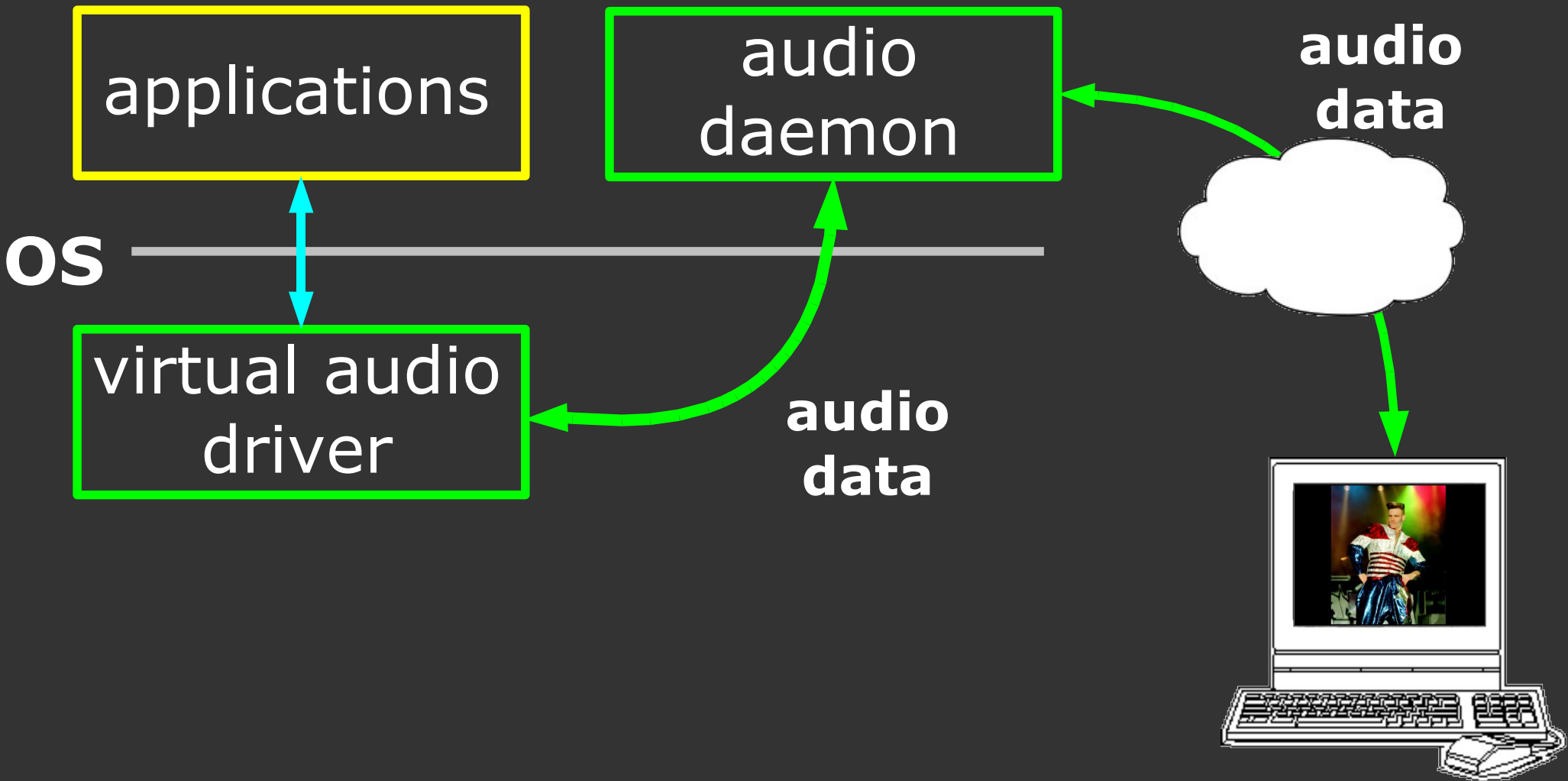
THINC multimedia

- native support for video playback
- bidirectional audio
- synchronized audio/video playback
- format independent and transparent to applications

video playback

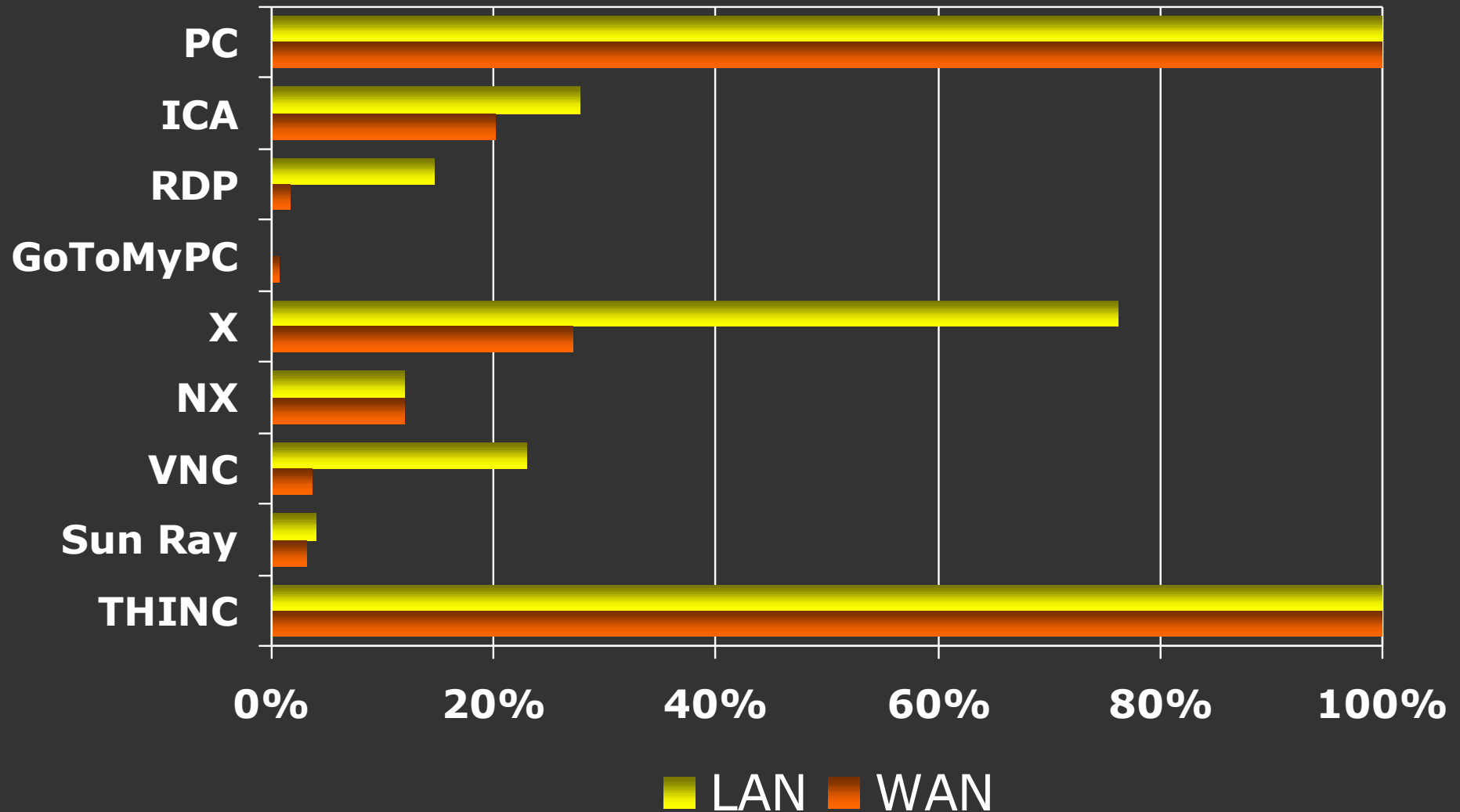


audio



experimental results

a/v playback quality



... perfect playback and up to two orders of magnitude better

mobile devices

- becoming ubiquitous
- have network connectivity
- but limited environment and applications

pTHINC

- provide superior remote display support for mobile devices
- competitive alternative to limited mobile applications

server-resized updates

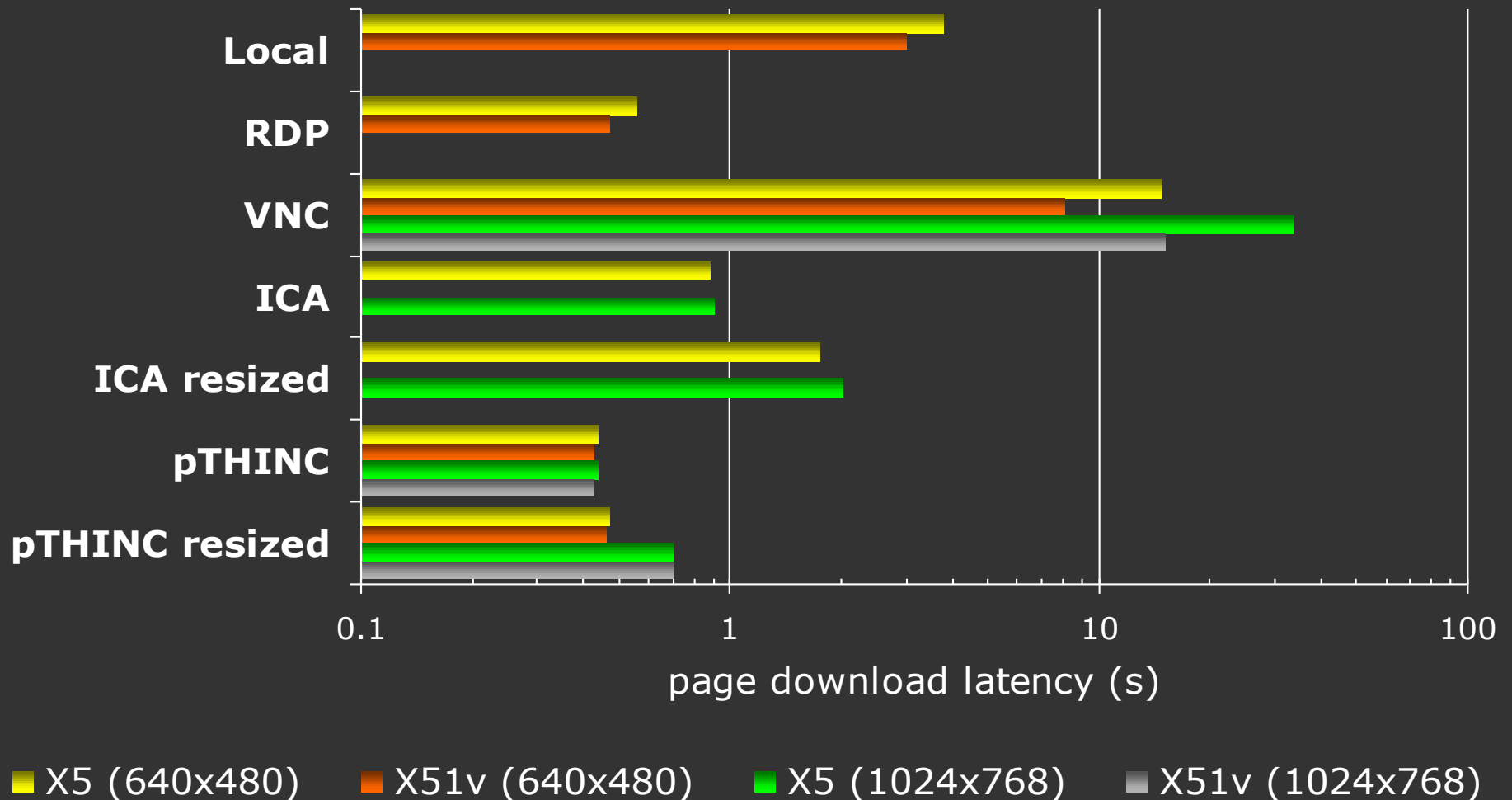


user interface

- zoom, scroll, rotate
- full screen by leveraging external controls

experimental results

PDA web browsing performance



**... up to 17x faster than other systems,
and up to 8x faster than native**

native vs pTHINC

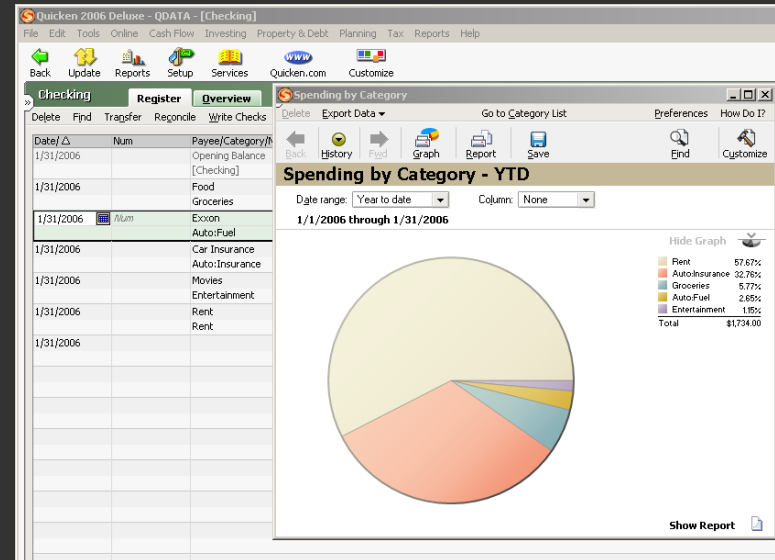
Pocket Quicken 9:19

Register Savings

Date	Ref and Payee	Amount
1/31/06	Opening Balance	10,000.00
1/31/06	Paycheck	2000.00
1/31/06	Rent	-1000.00
1/31/06	Food	-100.00
1/31/06	Gas	-50.00
1/31/06	Donations	-75.00
1/31/06	Gift	300.00

Current Balance: \$11,075.00
Ending Balance: \$11,075.00

New Tools



Internet Explorer 10:36

http://news.bbc.co.uk/

BBC NEWS

LATEST NEWS IN VIDEO AND AUDIO

UK version International version About the versions | Low graphics | Help

News Front Page Last Updated: Wednesday, 1 February 2006

Back Menu

http://news.bbc.co.uk/

BBC NEWS

UK version International version About the versions | Low graphics | Help

News Front Page LATEST: Researchers say they found link between eating red meat and the risk of bowel cancer. Last Updated: Wednesday, 1 February 2006, 03:11 GMT

Bush vows to face dangers head on

The US president warns of "danger and decline" if the US fails to face down threats, in his State of the Union speech.

Iran issues inspections warning

Iran says it will end snap UN checks of its nuclear facilities if a decision is taken to report it to the UN Security Council.

Saddam due in court after walkout

The trial of Saddam Hussein is set to resume, after the former Iraqi leader walked out of court on Sunday.

OTHER TOP STORIES

- Thousands arrested in Ethiopia
- Ferry sinks in eastern Indonesia
- Lee's brokeback leads Oscar race
- Ecuador steps up border security
- Iraqi group sets hostage deadline
- Google set to fall on profit miss

ALSO IN THE NEWS

- Kenya says aid offer from New Zealand dog food firm in 'bad taste'
- How a ride on a ski lift gave a deaf man back his hearing

BBC SPORT

- Cricket: Pakistan pile on misery
- Cricket: S Africa close in on final

Helping hand One small step to help Afghanistan's fledgling

Hollywood hopefuls Who are the favourites in the race for Oscar

The tiny test Miniature fish vie for the title of the world's

btw

limitations

- need better compression
 - NX/SunRay/VNC, adaptive
- multimedia
 - too much bandwidth?
 - limited on mobile devices
 - flash video
- no support for new generation of high-end desktops and 3D applications

impact

- Technology licensed for commercial use
- VESA standard in progress

conclusions

- high performance remote display system able to outperform existing solutions
- first to provide full support for multimedia content, transparently to applications and independent of format
- superior remote display support for mobile devices

backup

Page-by-page comparison

- THINC faster on all pages except image-only
- Our approach works better than both low and high-level on non-image content

Microbenchmarks

- It's not each individual component, but the combination
- Not clear microbenchmark results can be extrapolated to overall performance
- But do have some results:
 - No offscreen: ~70% (all RAW)
 - Only interception and redirection: ~225%

future work

- remote display standard (Net2Display)
- 3D
- indexing and searching improvements

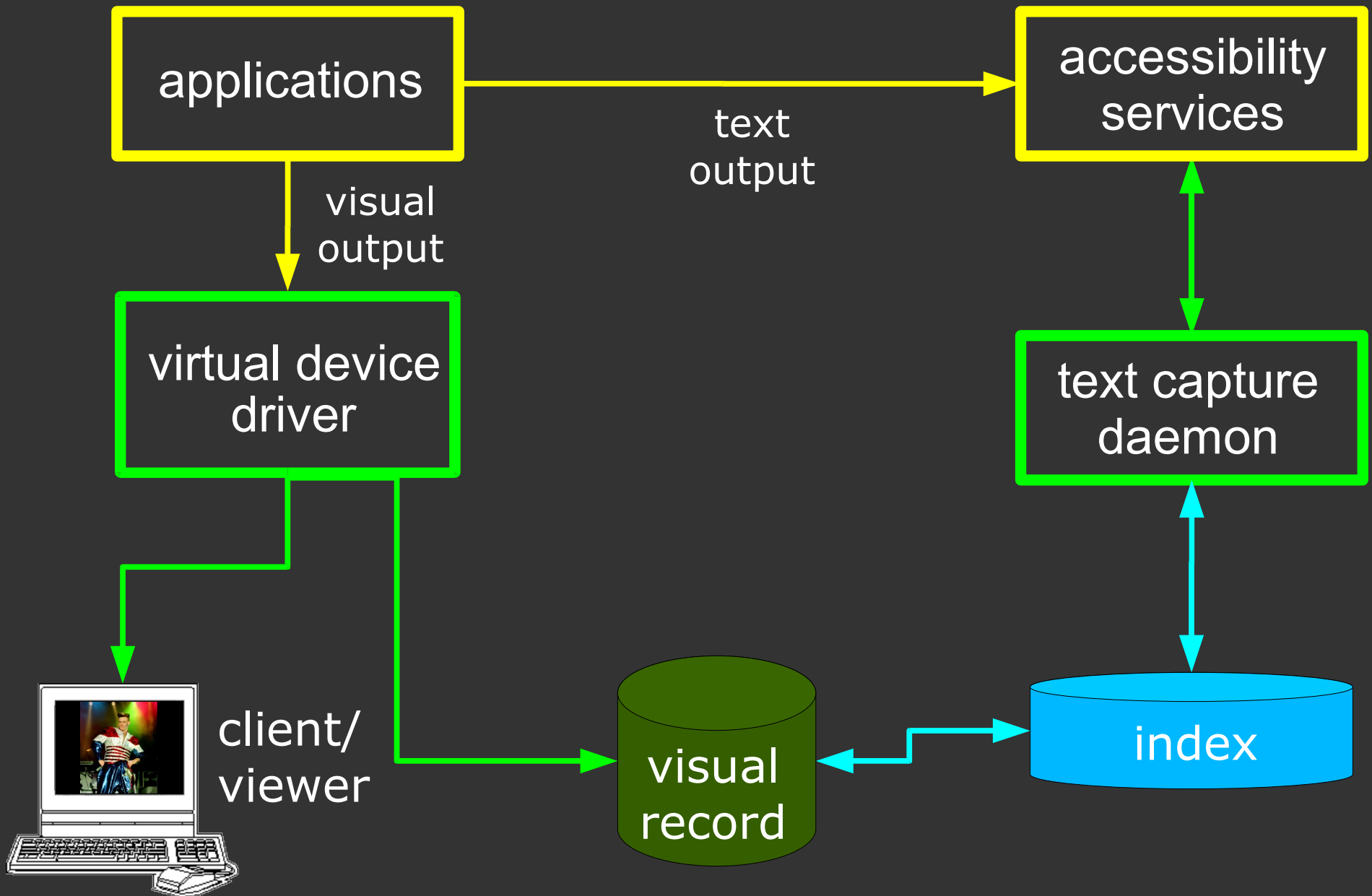
list of publications

- MobiDesk: Mobile Virtual Desktop Computing [MobiCom 04]
- THINC: A Virtual Display Architecture for Thin-Client Computing [SOSP 05]
- Remotely Keyed Cryptographics: Secure Remote Display Access Using (Mostly) Untrusted Hardware [ICICS 05]
- pTHINC: A Thin-Client Architecture for Mobile Wireless Web [WWW 06]
- An Application Streaming Service for Mobile Handheld Devices [SCC 06]
- Net2Display: A Proposed VESA Standard for Remoting Displays and I/O Devices over Networks [ADEAC 06]
- DejaView: A Personal Virtual Computer Recorder [SOSP 07]

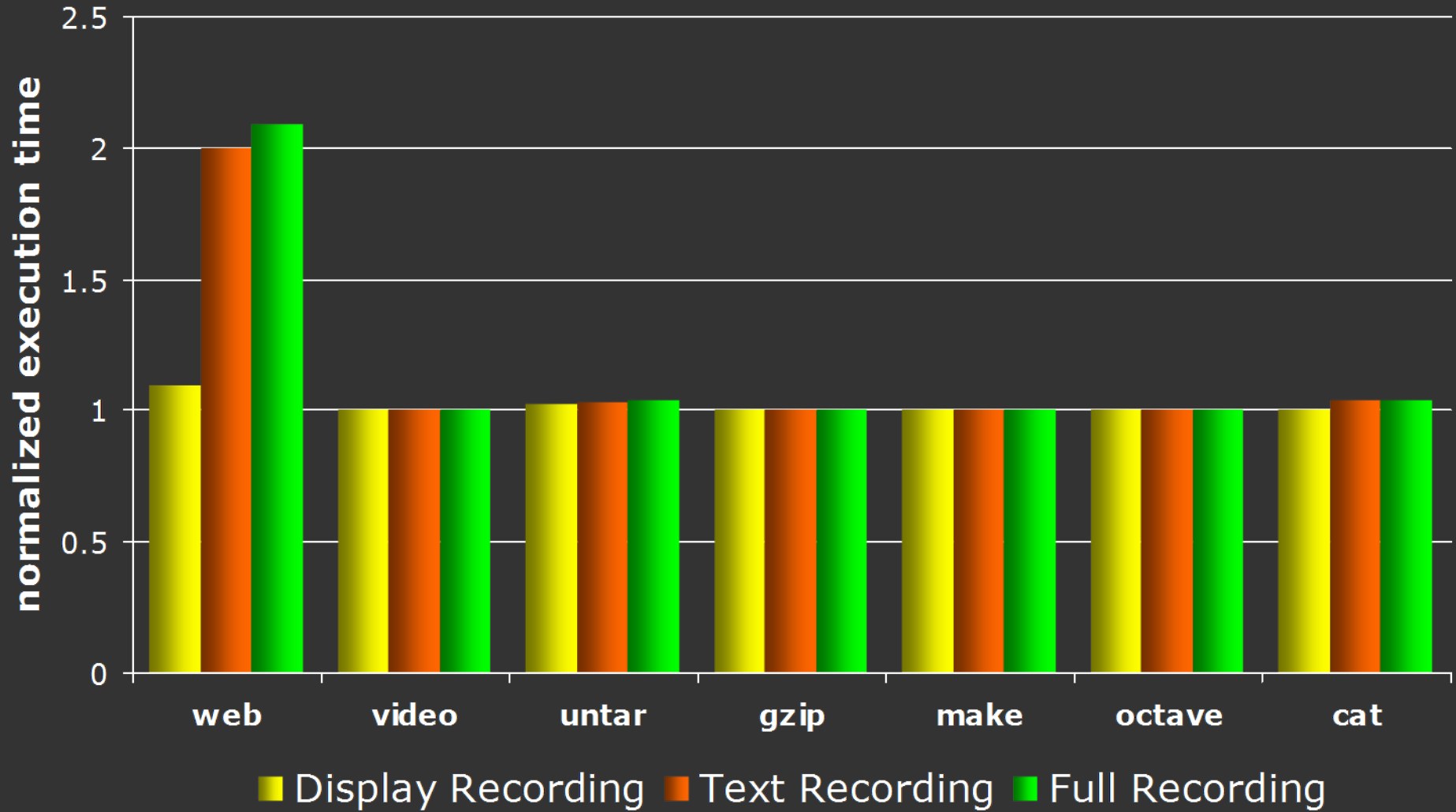
beyond remote display: desktop recording

- provide recording of all desktop output
- allow recording to be searched

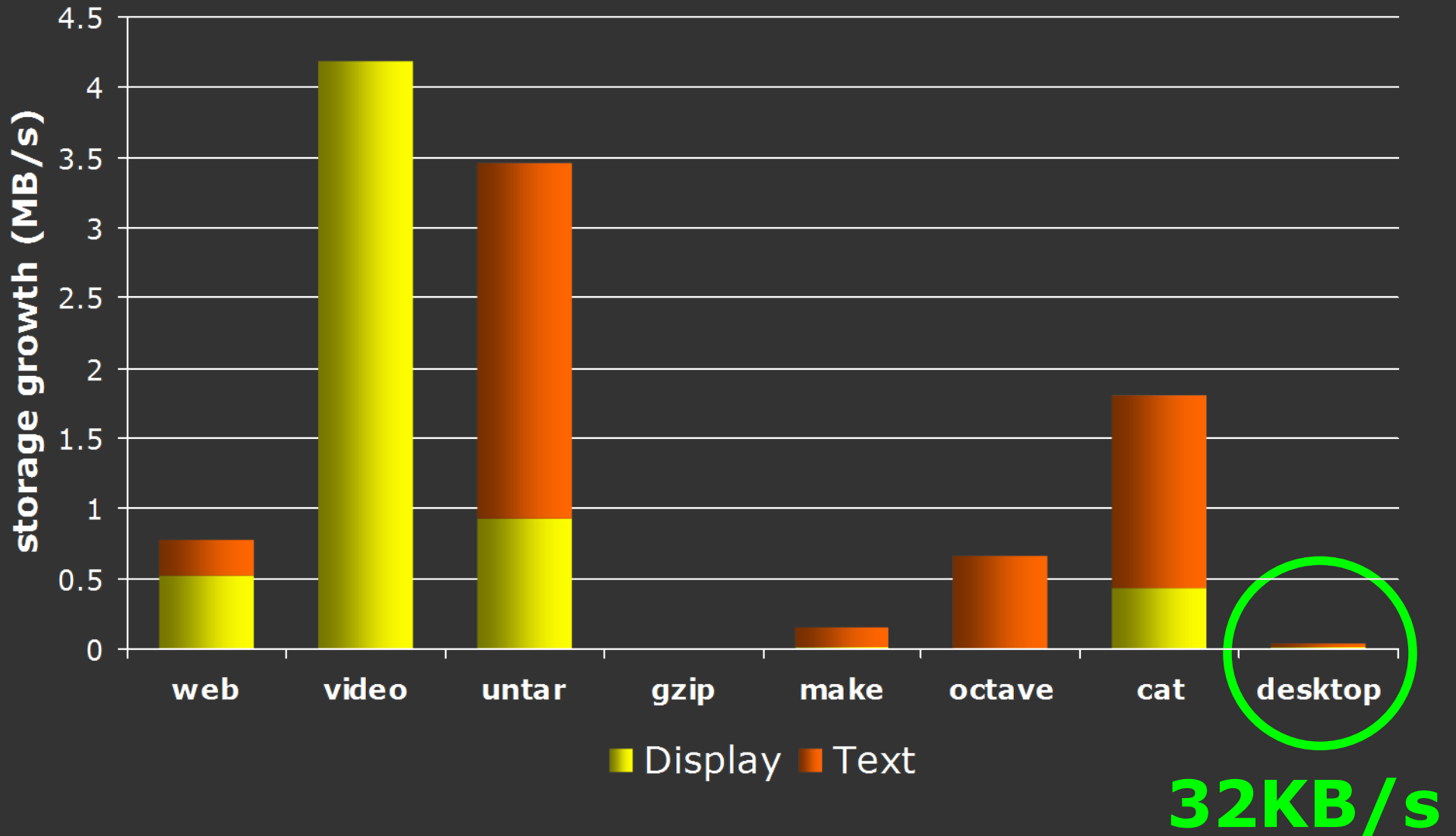
desktop recording



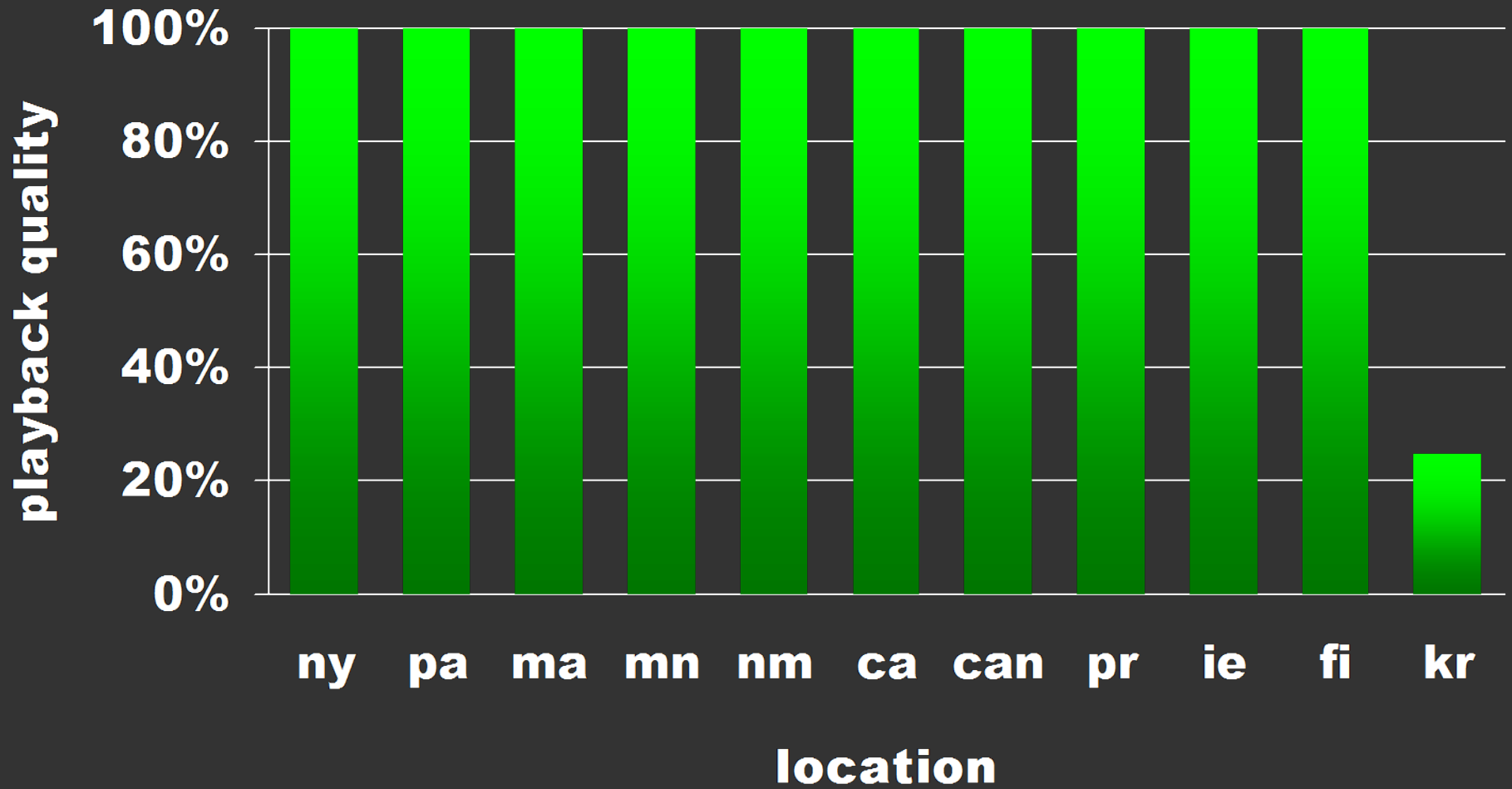
recording runtime overhead



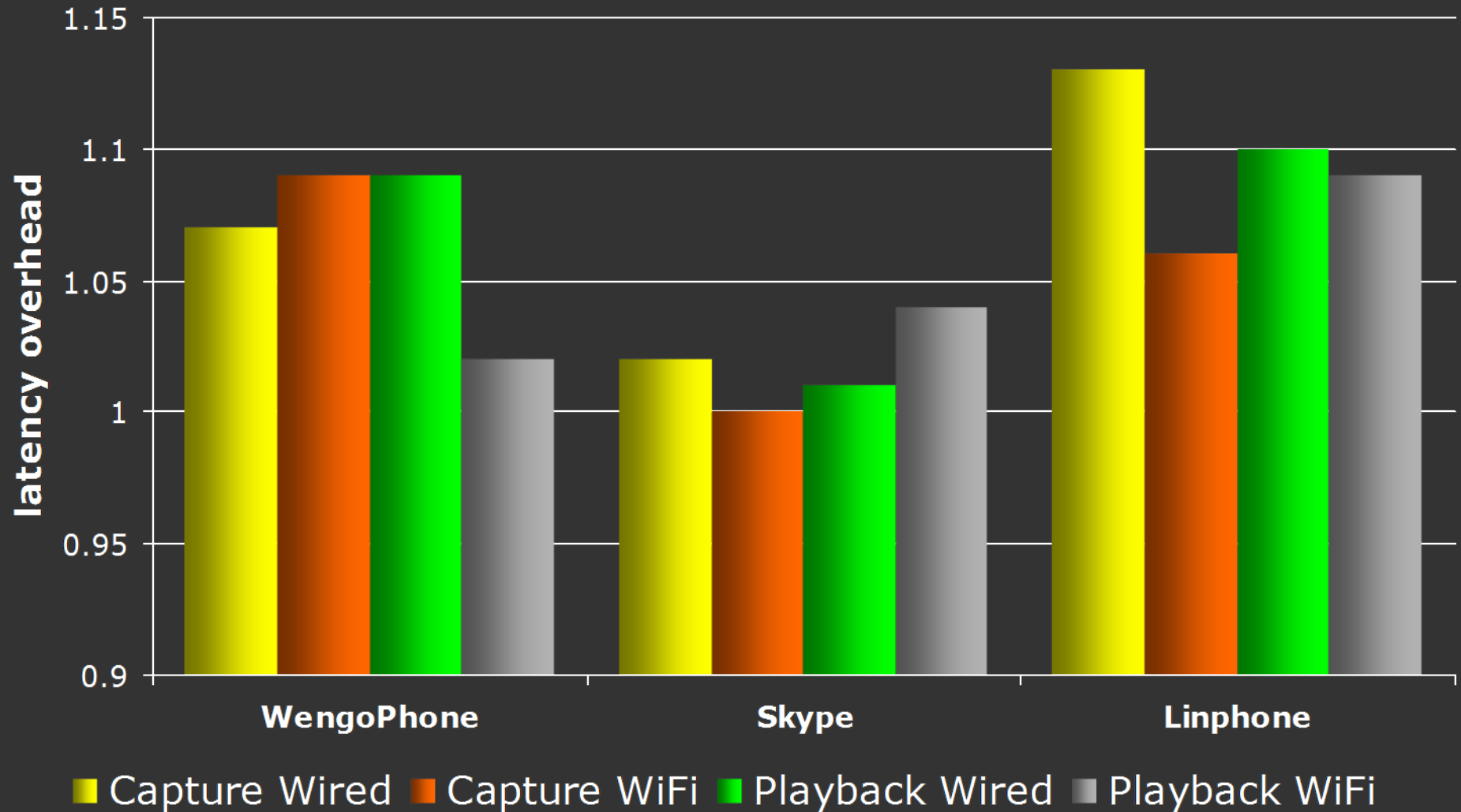
storage growth



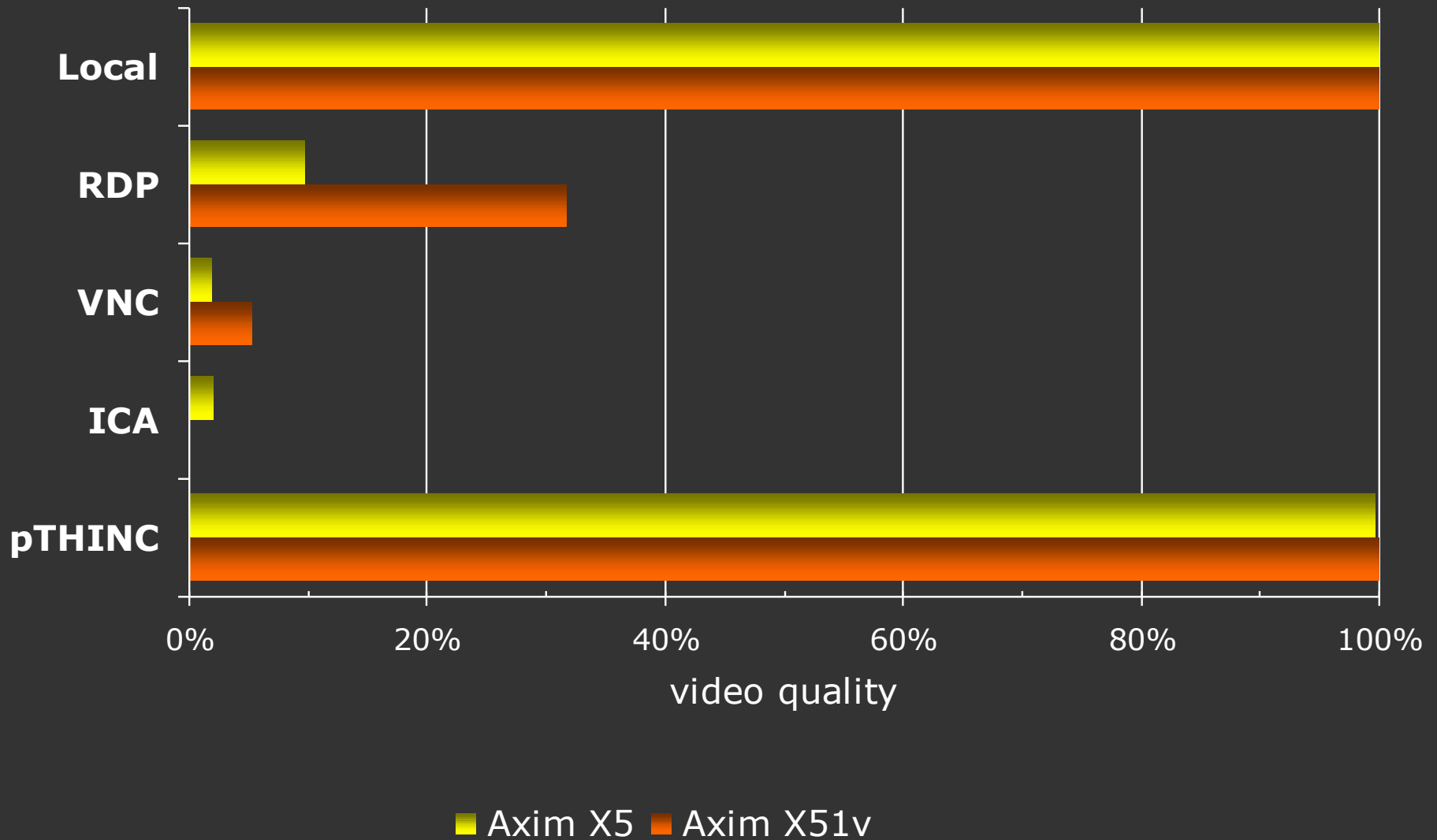
wan a/v playback quality



mouth-to-ear latency overhead



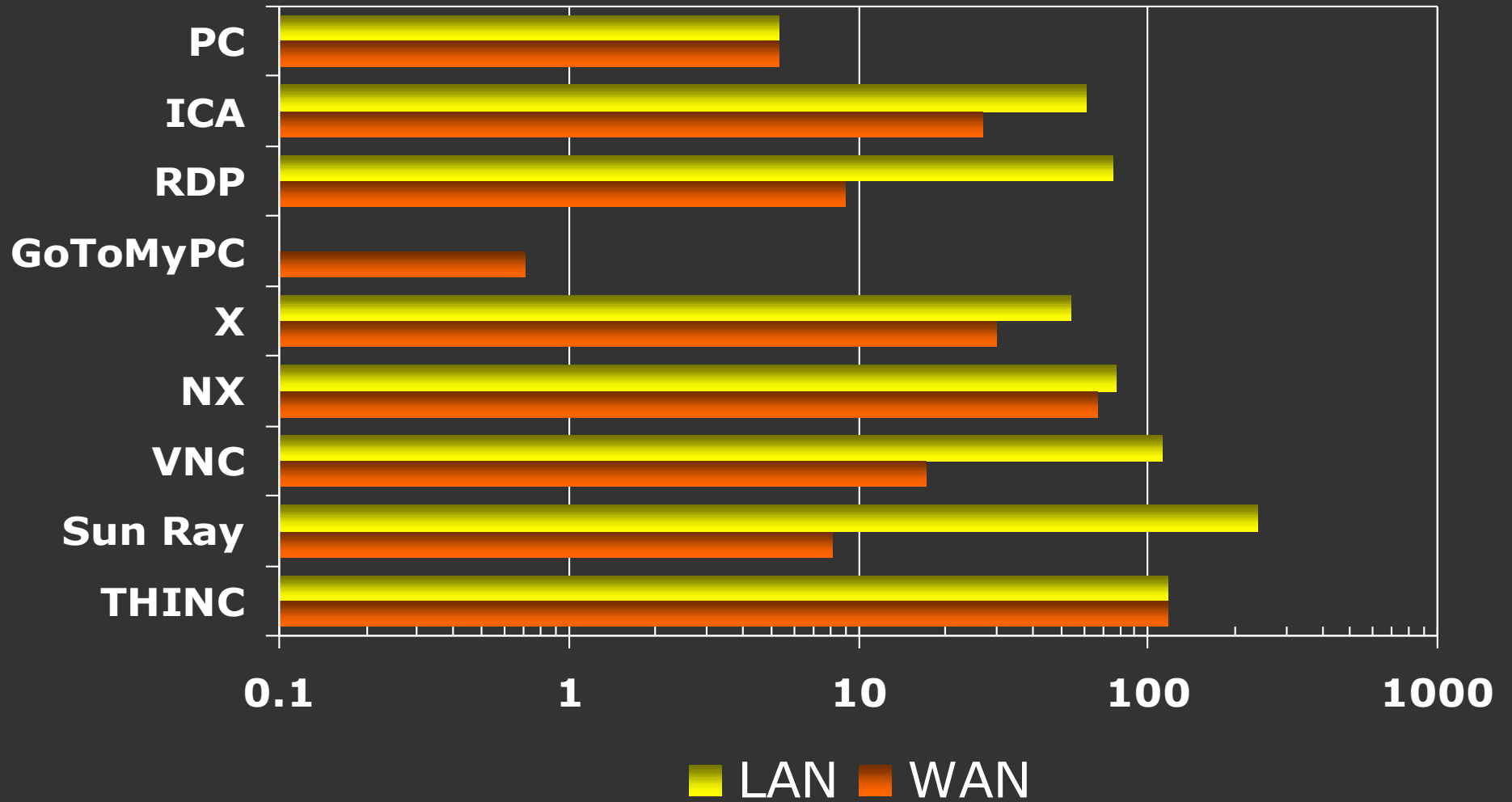
PDA video playback quality



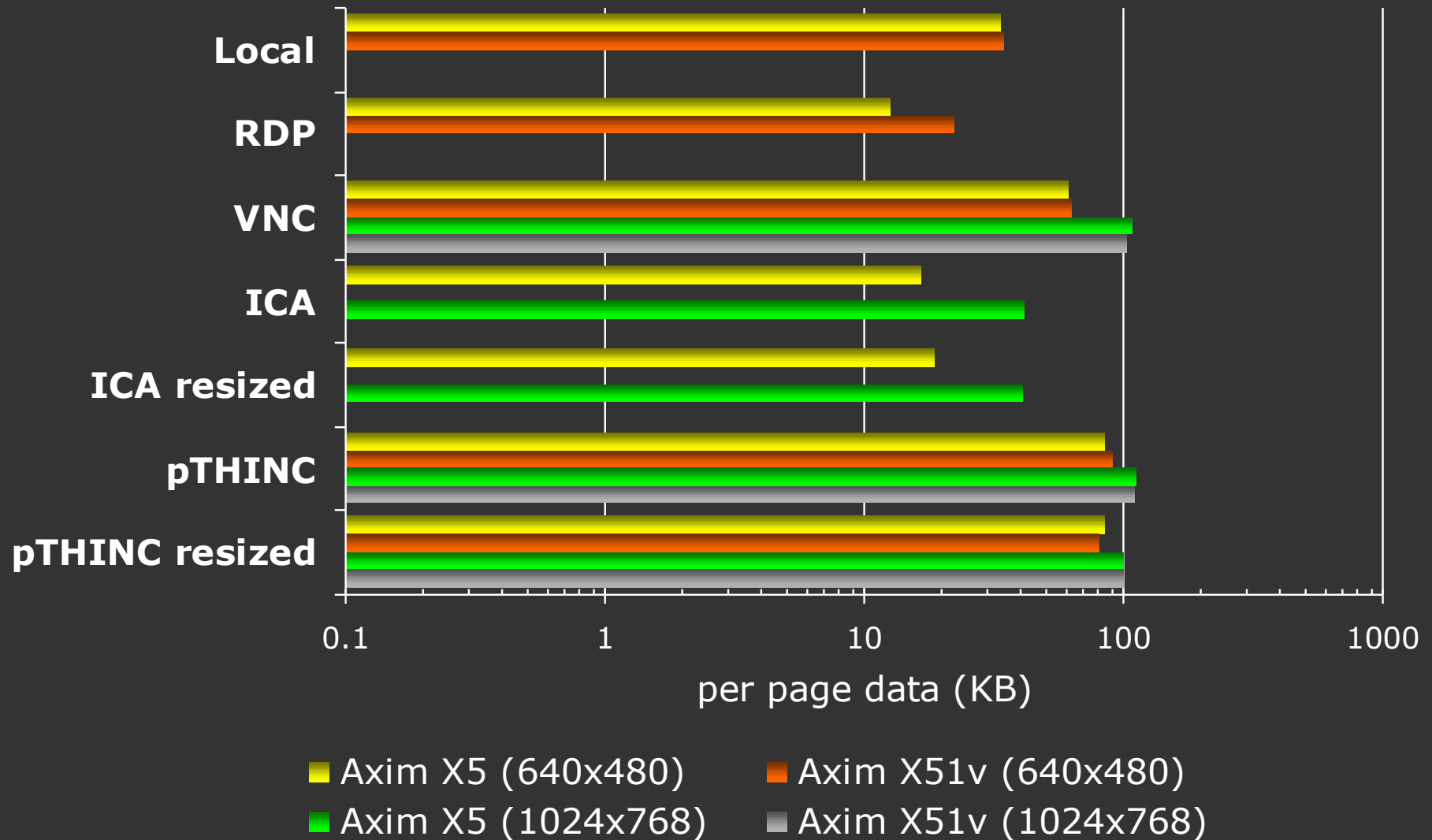
web browsing data transfer



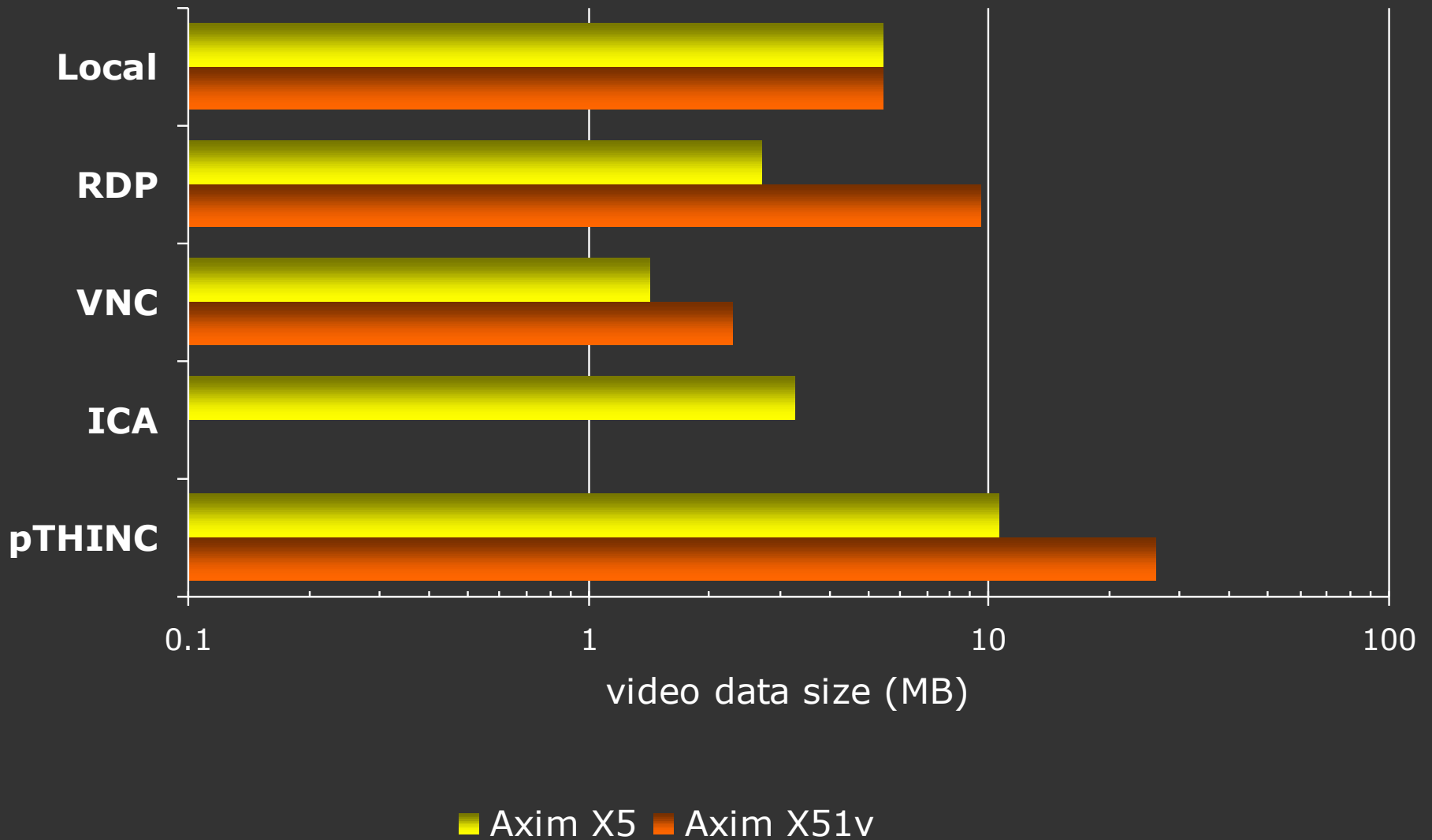
A/V data transfer



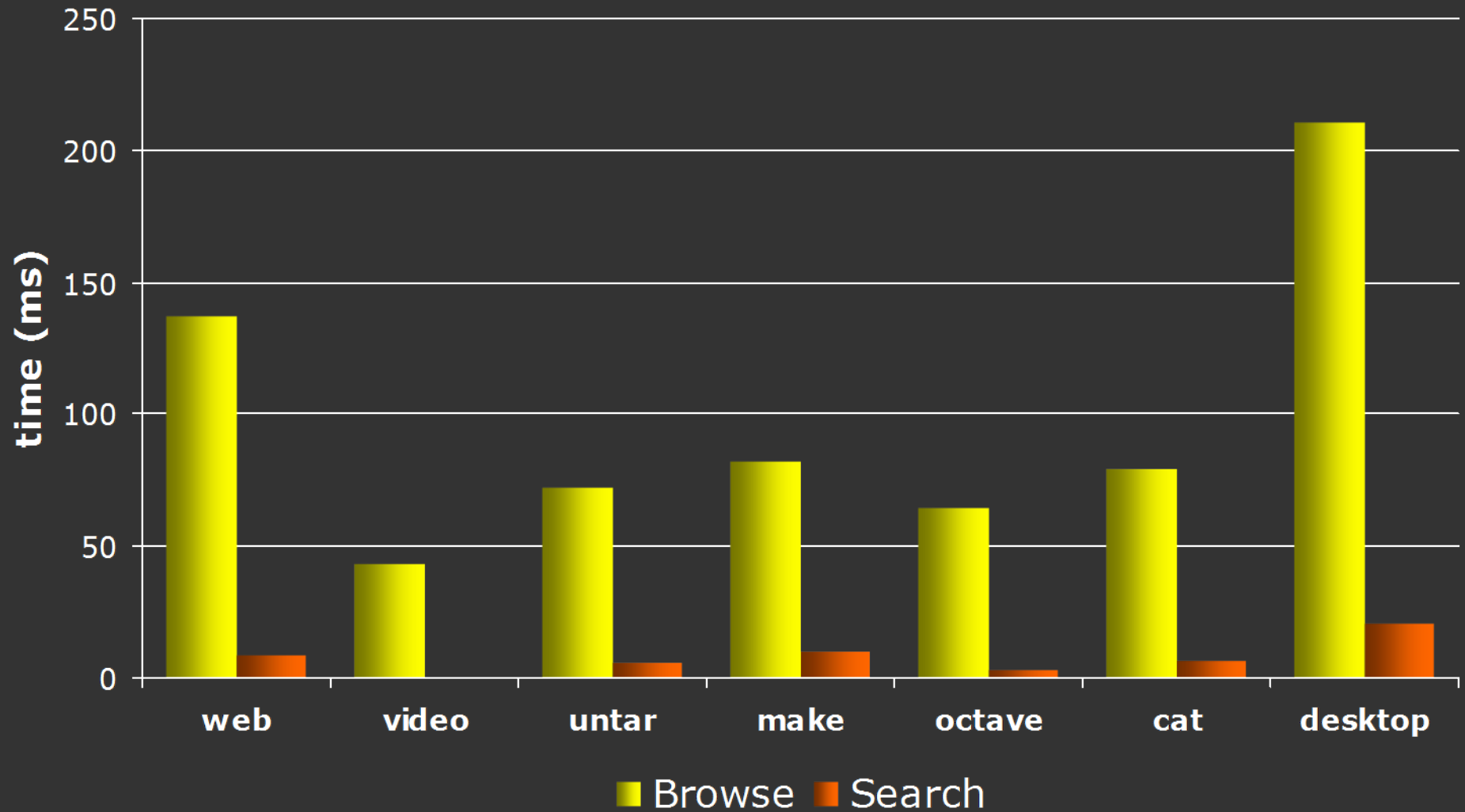
PDA web browsing data transfer



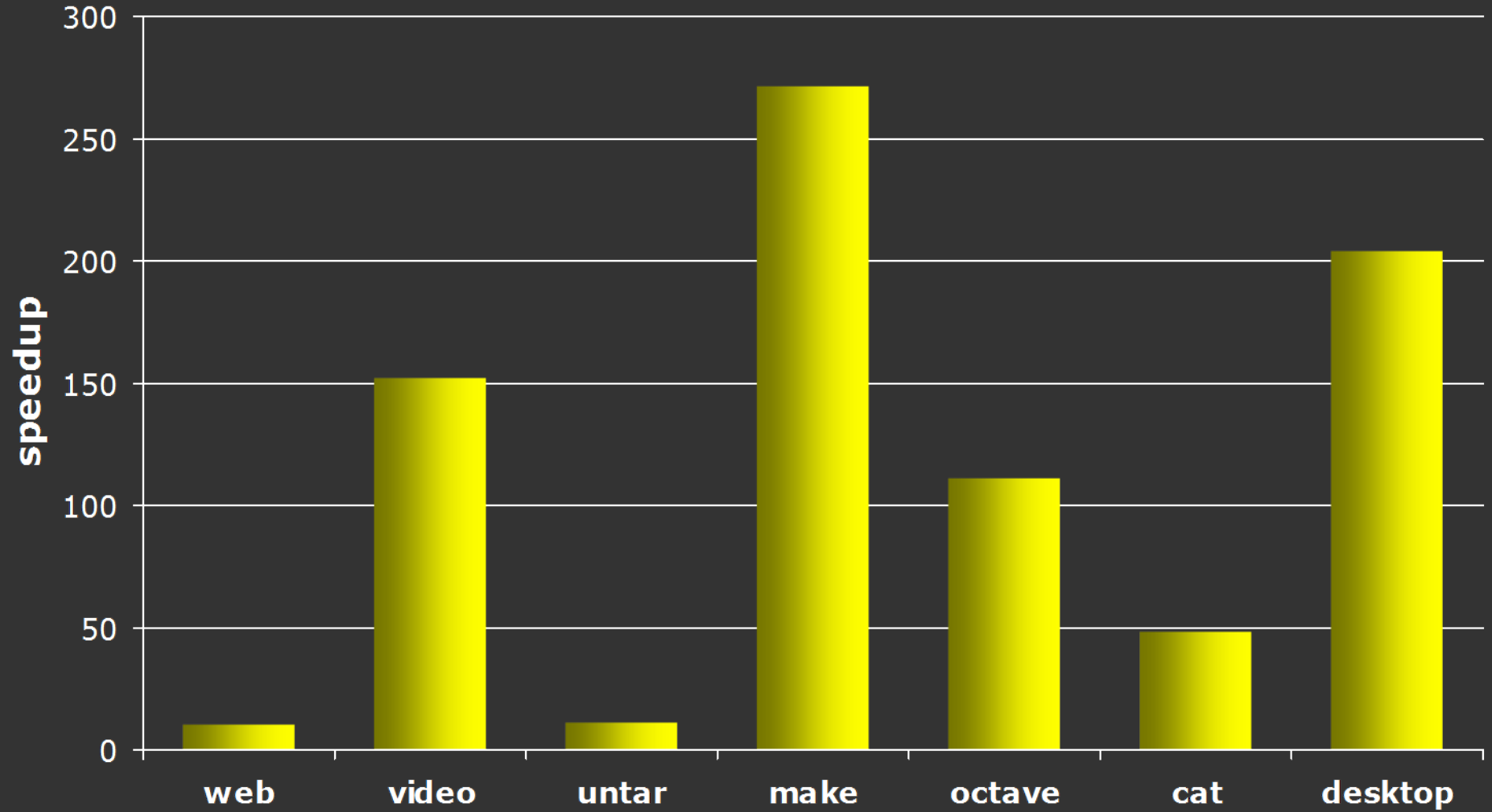
PDA video data transfer



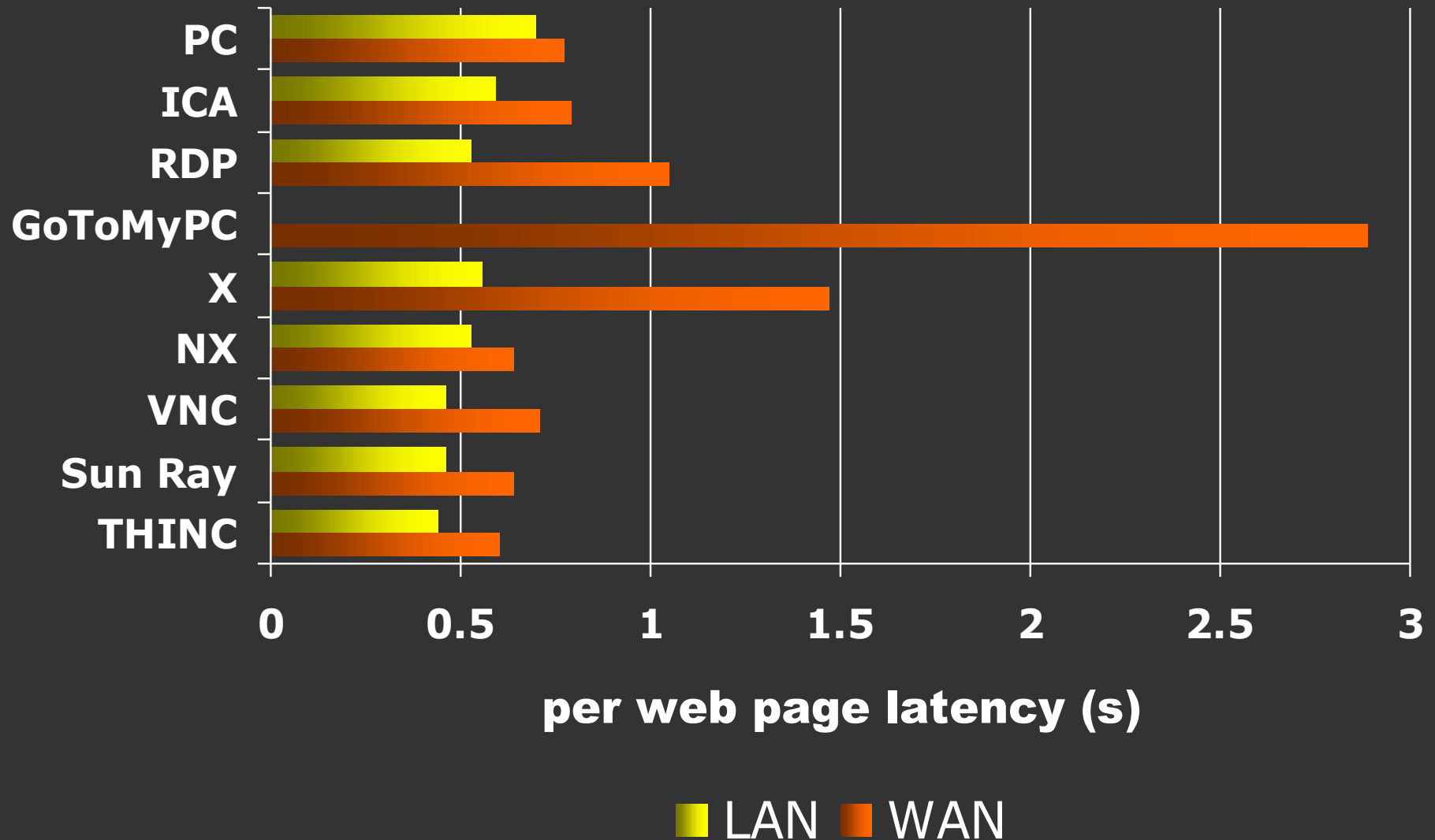
browse and search latency



playback speedup

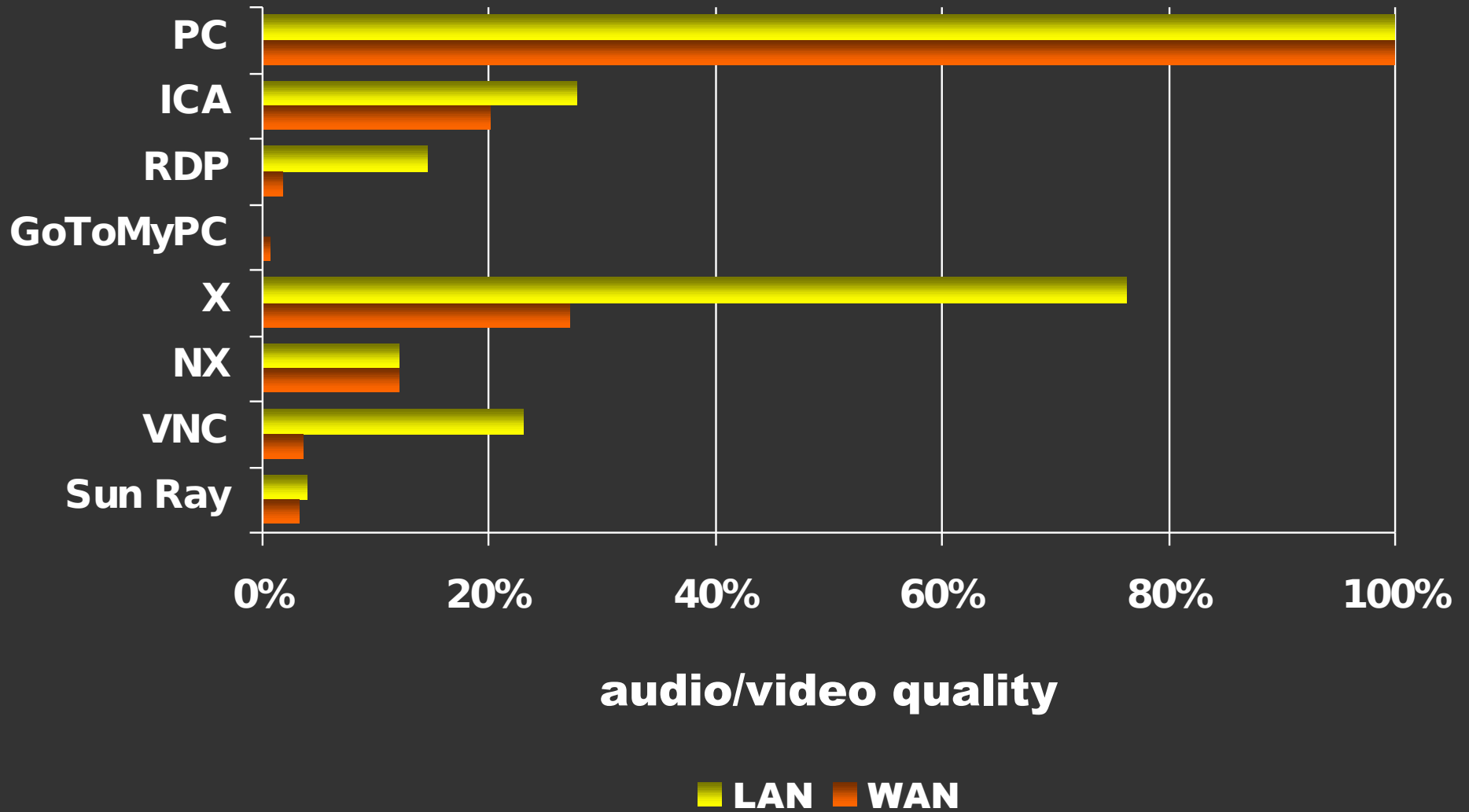


web browsing performance



... up to 4.8 times better performance

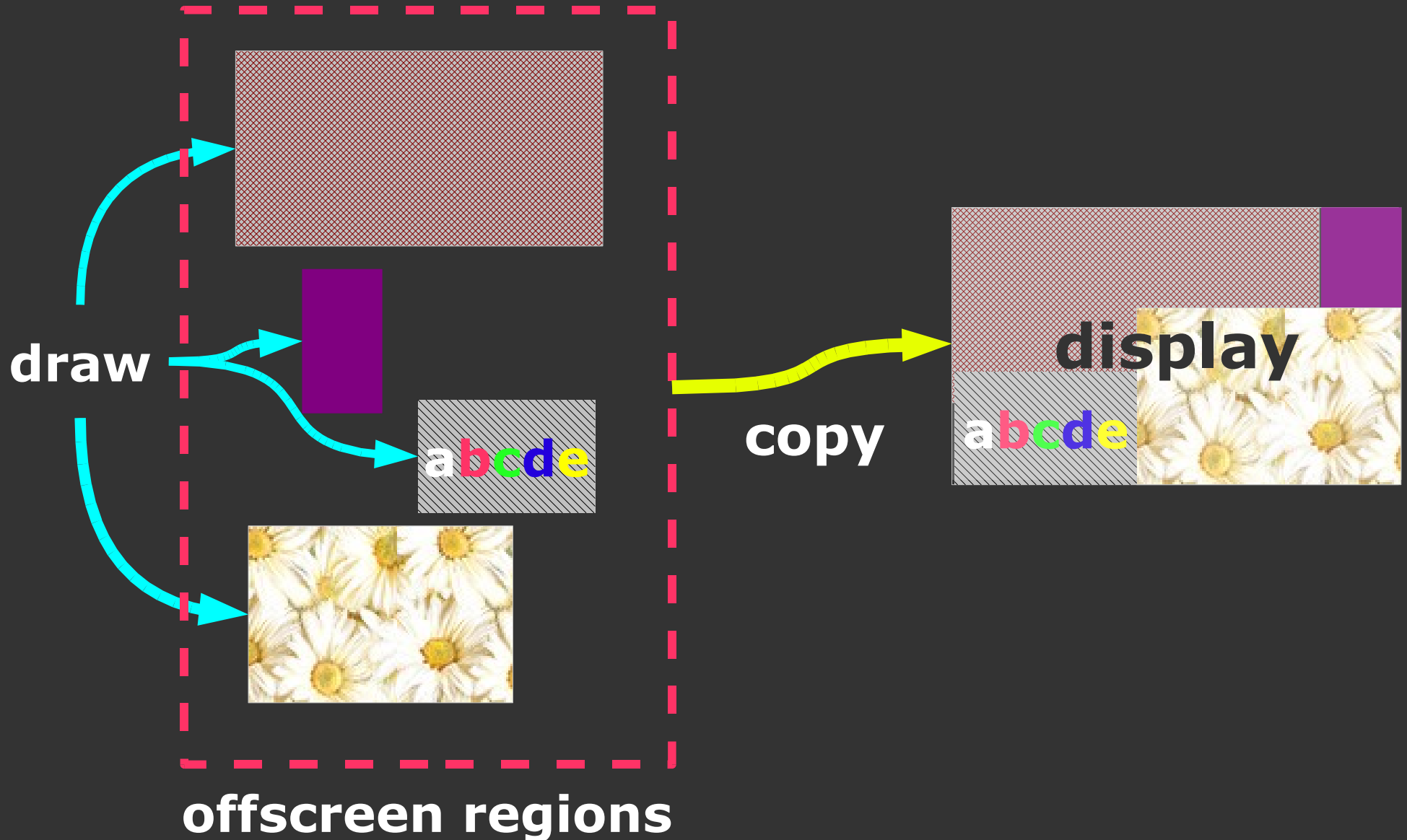
existing performance problem



implementation

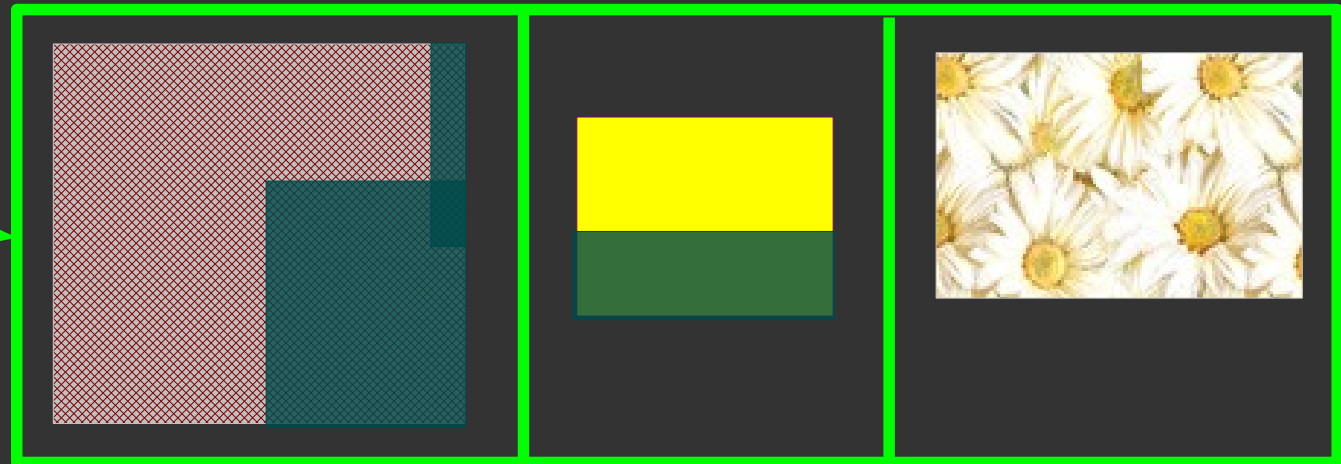
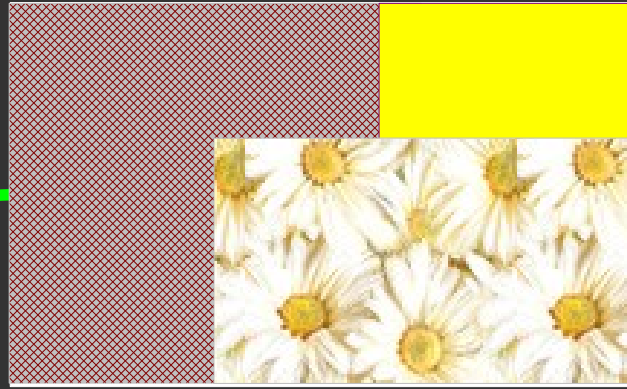
- X/Linux and windows display server
- Linux audio driver (alsa) + daemon
- X/Linux windows, PDA, and Java clients
- X/Linux desktop recording
 - capture using ATK (Gnome)
 - index using Postgres + Tsearch2

offscreen drawing



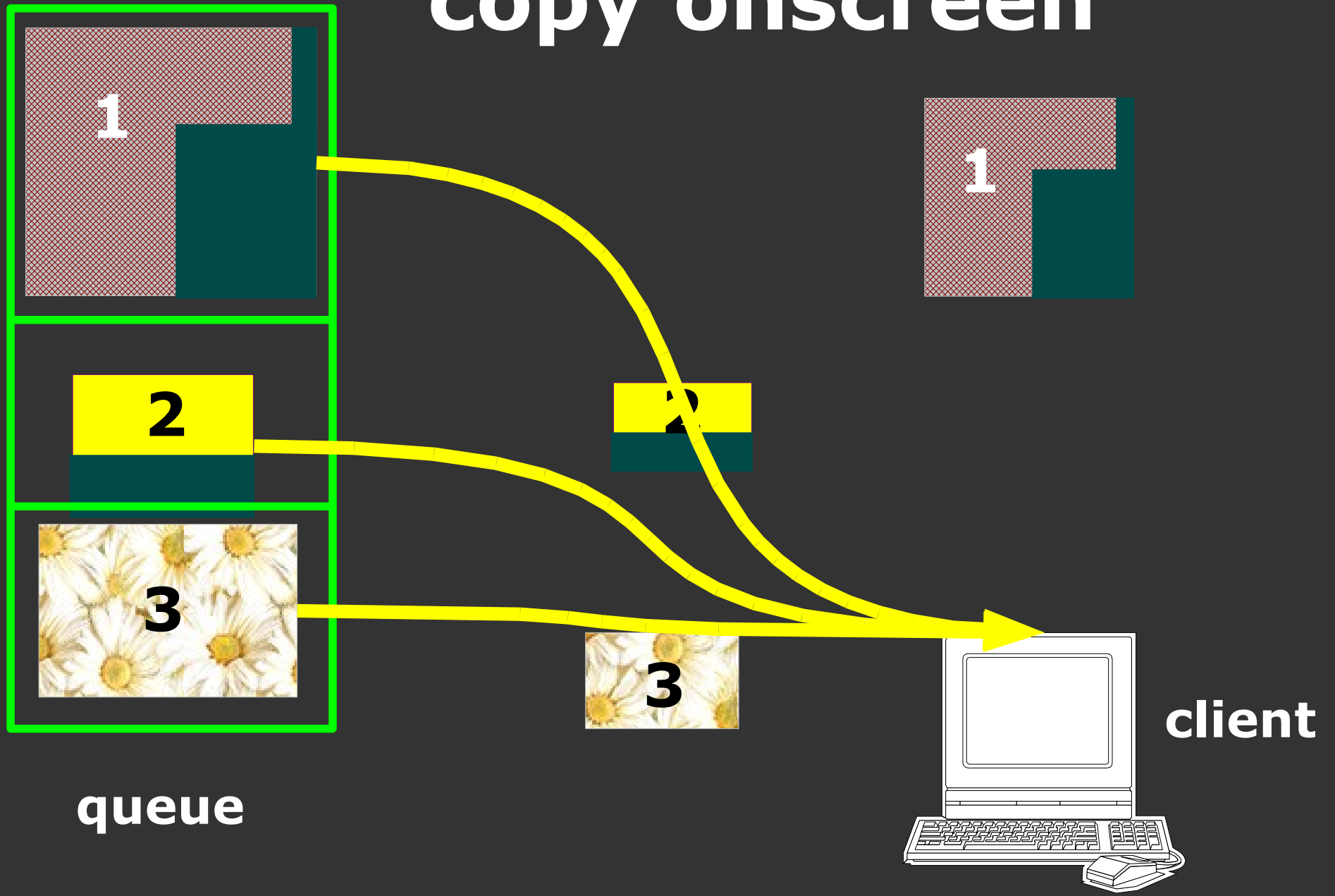
command queues

offscreen region

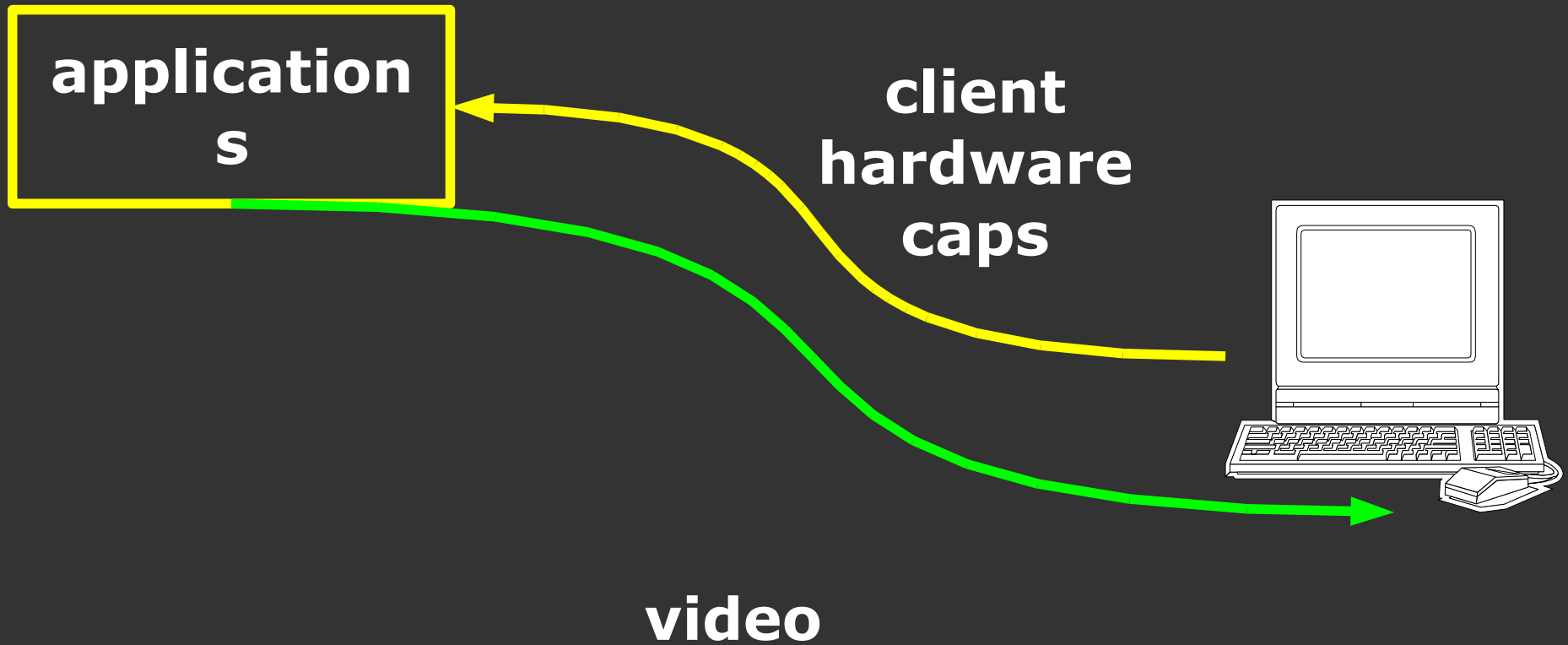


command queue

copy onscreen

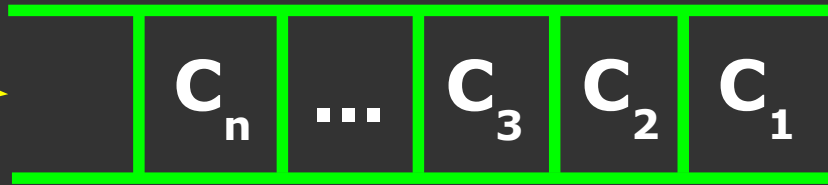


how?

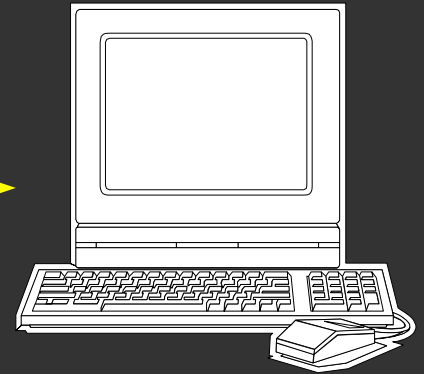


how we deliver updates

display
updates



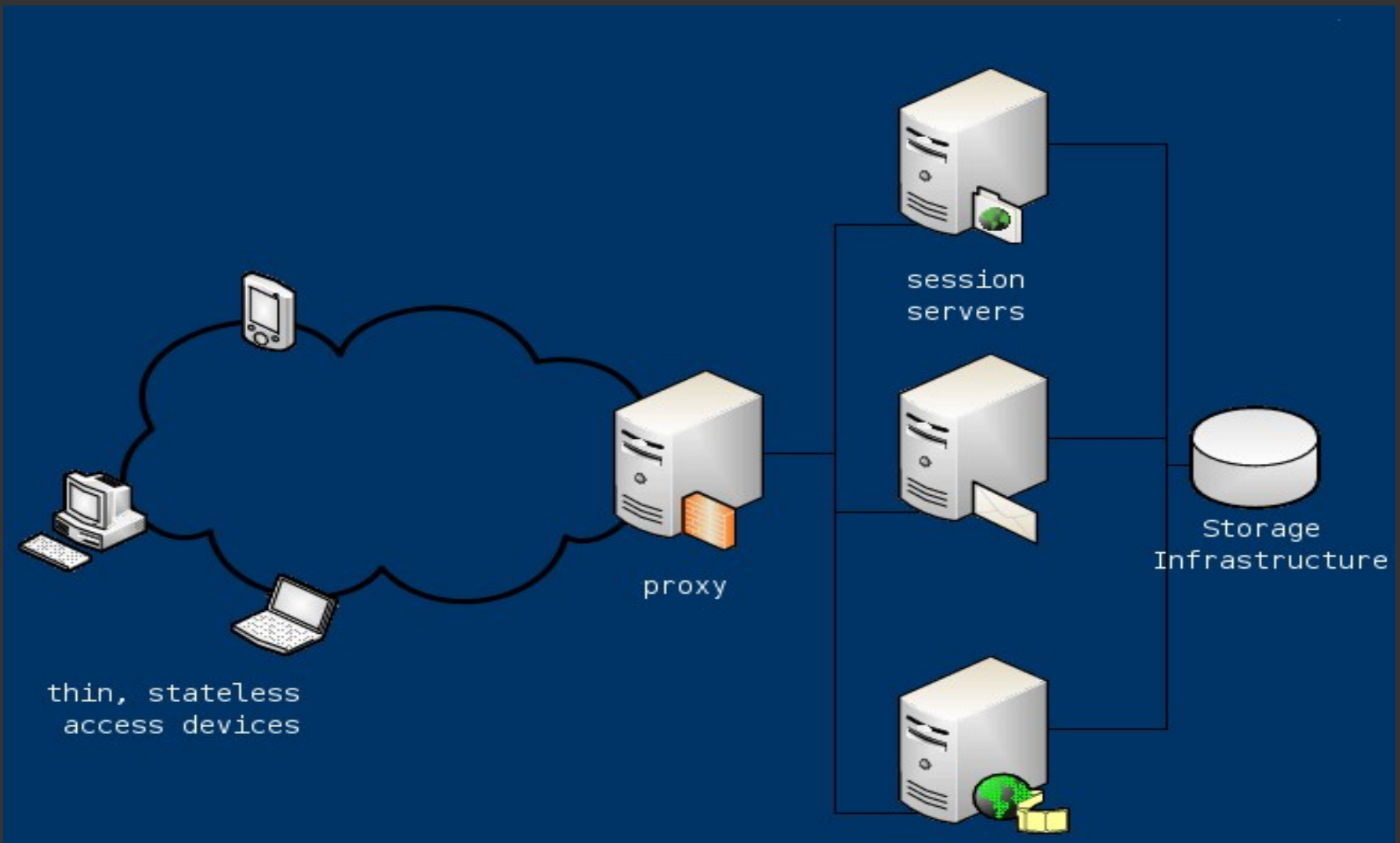
client buffer



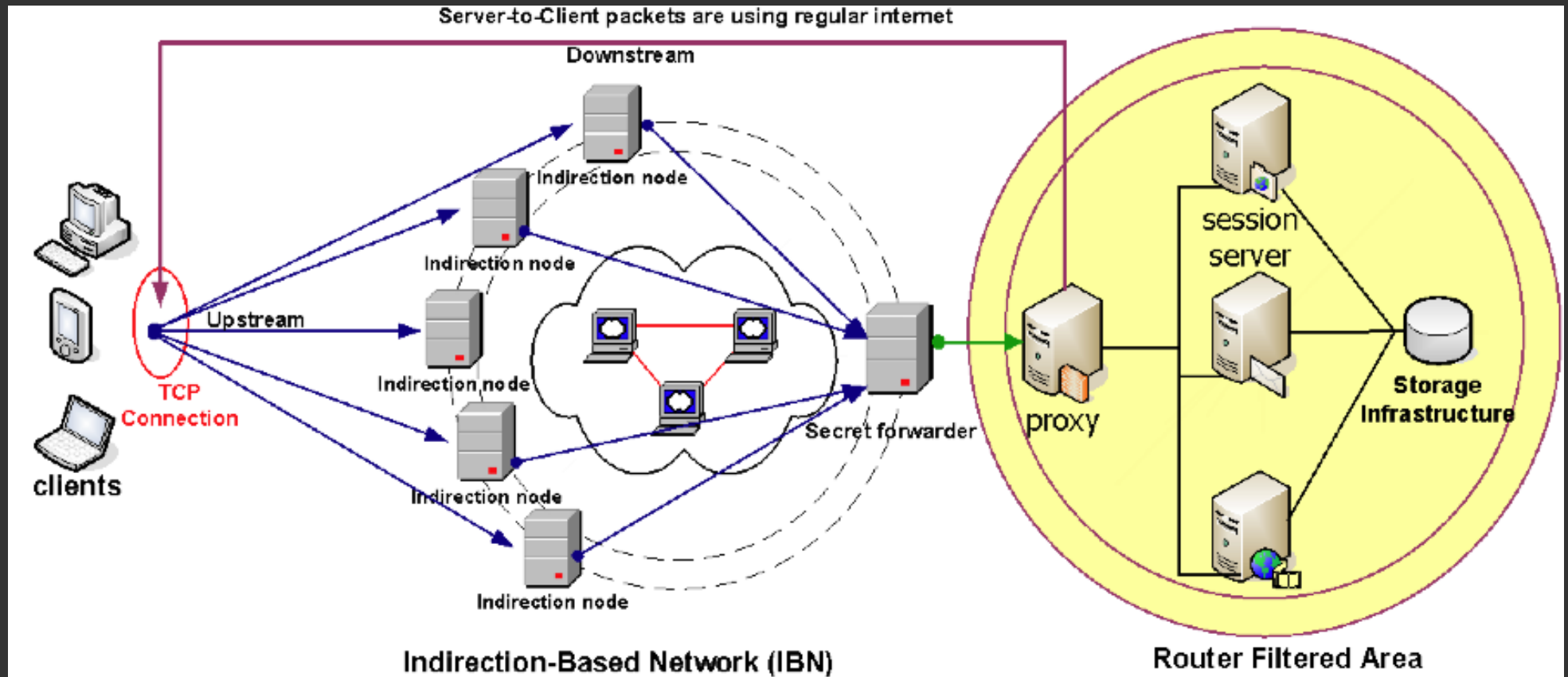
desktop virtualization

- decouple desktop from underlying video hardware
- encapsulate window and graphical state
- can move around:
 - carry in pocket
 - around hosting servers

MobiDesk



A²M: Access Assured Mobile Desktop Computing



old slides

contributions

- high performance remote display system [[SOSP 05](#)]
 - focus on system architecture to improve performance
 - outperforms existing systems
- first to natively support multimedia applications
 - transparent and format-independent
- wireless mobile device support [[WWW 06](#), [SCC 06](#)]
 - server-side display scaling for improved display quality and performance
 - user interface tailored for constrained environment

contributions II

- MobiDesk: desktop utility computing infrastructure [[MobiCom 04](#)]
 - fully virtualized environment for hosting desktops
 - hosted sessions can be migrated for high availability
- A²M: protect MobiDesk from DDoS attacks
 - indirection-based network + remote display
 - exploit asymmetric traffic to minimize overhead
- beyond remote display: desktop recording [[SOSP 07](#)]
 - low overhead recording, and efficient access
 - novel use of accessibility services for indexing and searching

display protocol

Inspired on Sun Ray protocol

2D Primitives

- **copy**
- **solid and tile fill**
- **bitmap fill**
- **raw**

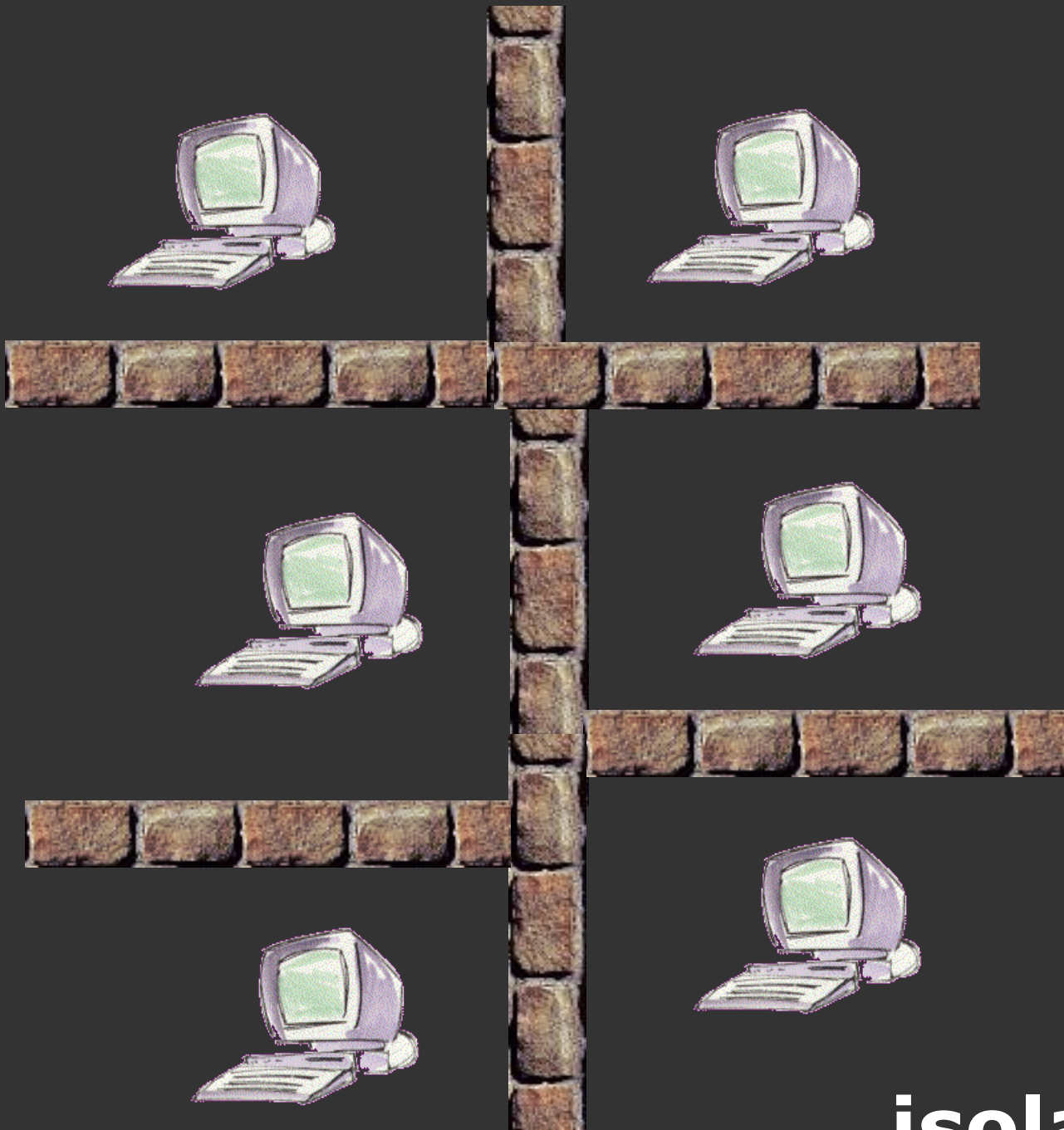
demo

video

- leverage existing hardware acceleration interfaces
- YUV (luminance-chrominance) color space
 - format independence
 - client hardware acceleration (scaling for free)

YUV

- **Standard hardware interface**
- **Format independence**
- **Hardware acceleration (fullscreen for free!)**



isolation...

CITRIX®

REAL
VNC

Microsoft
Windows xp

GoToMyPC

NOMACHINE
BUILDING THE NETWORK COMPUTING ON THE POWER OF X



X

... and a PC

- system architecture
 - as important
- as protocol and encoding

goals

- **minimize latency**
- **simple and portable**
- **transparent operation**

**application
requests**

**display
updates**

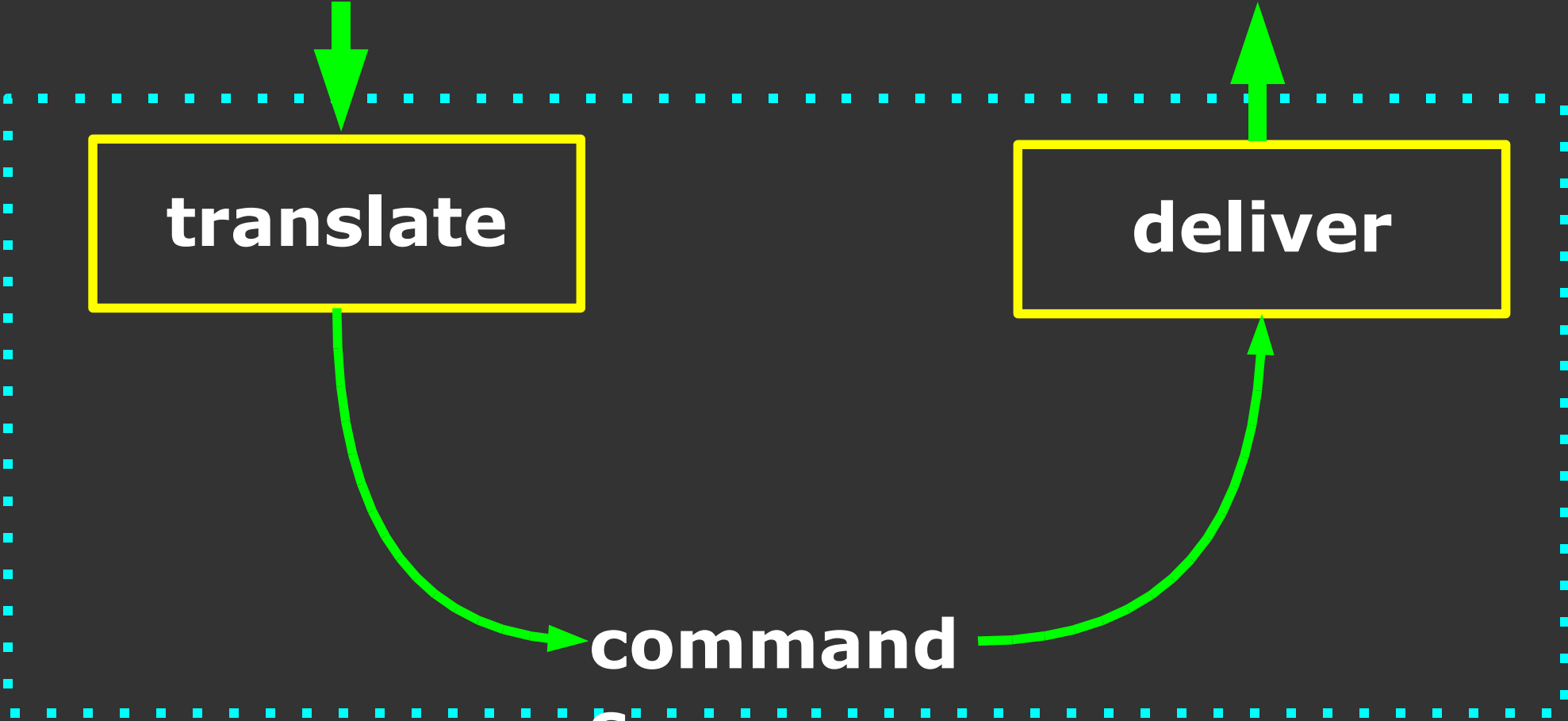
translate

deliver

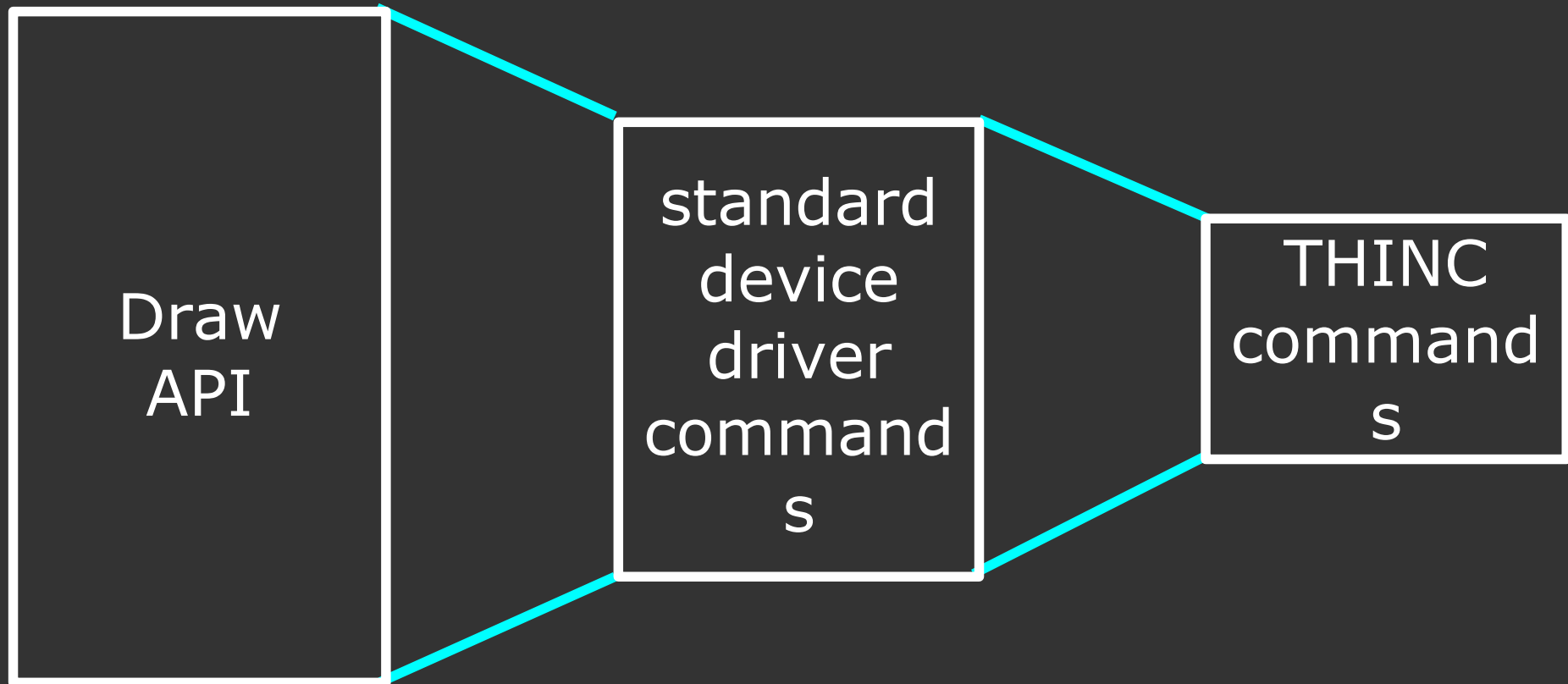
command

S

THINC



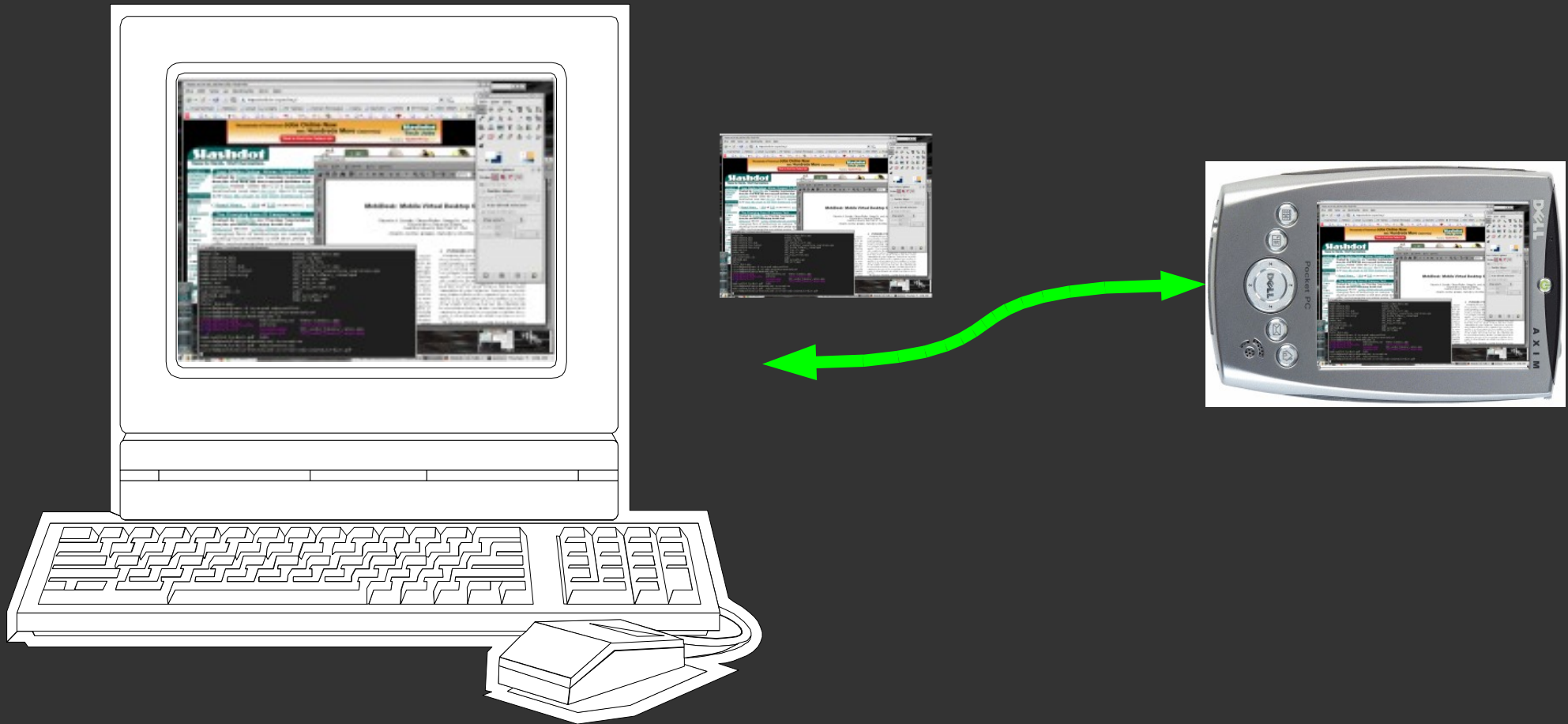
basic static translation



THINC

- high performance remote display
- LAN and WAN environments
- transparent operation in existing desktop systems
- full screen, full motion audio/video playback

server-resized updates



system architecture

two key problems

**how do we translate
from application commands
to the display protocol?**

**how and when do we send
display updates?**

but...

- performance problems
 - issues supporting display intensive interactive applications
 - issues coping with higher latency network environments
- lack of “features”
 - limited or no support for multimedia content
 - subpar support for mobile devices

system architecture is key

- **interception**
- **translation**
- **delivery**