thin clients: back to the future

<Jason Nieh> nieh@cs.columbia.edu

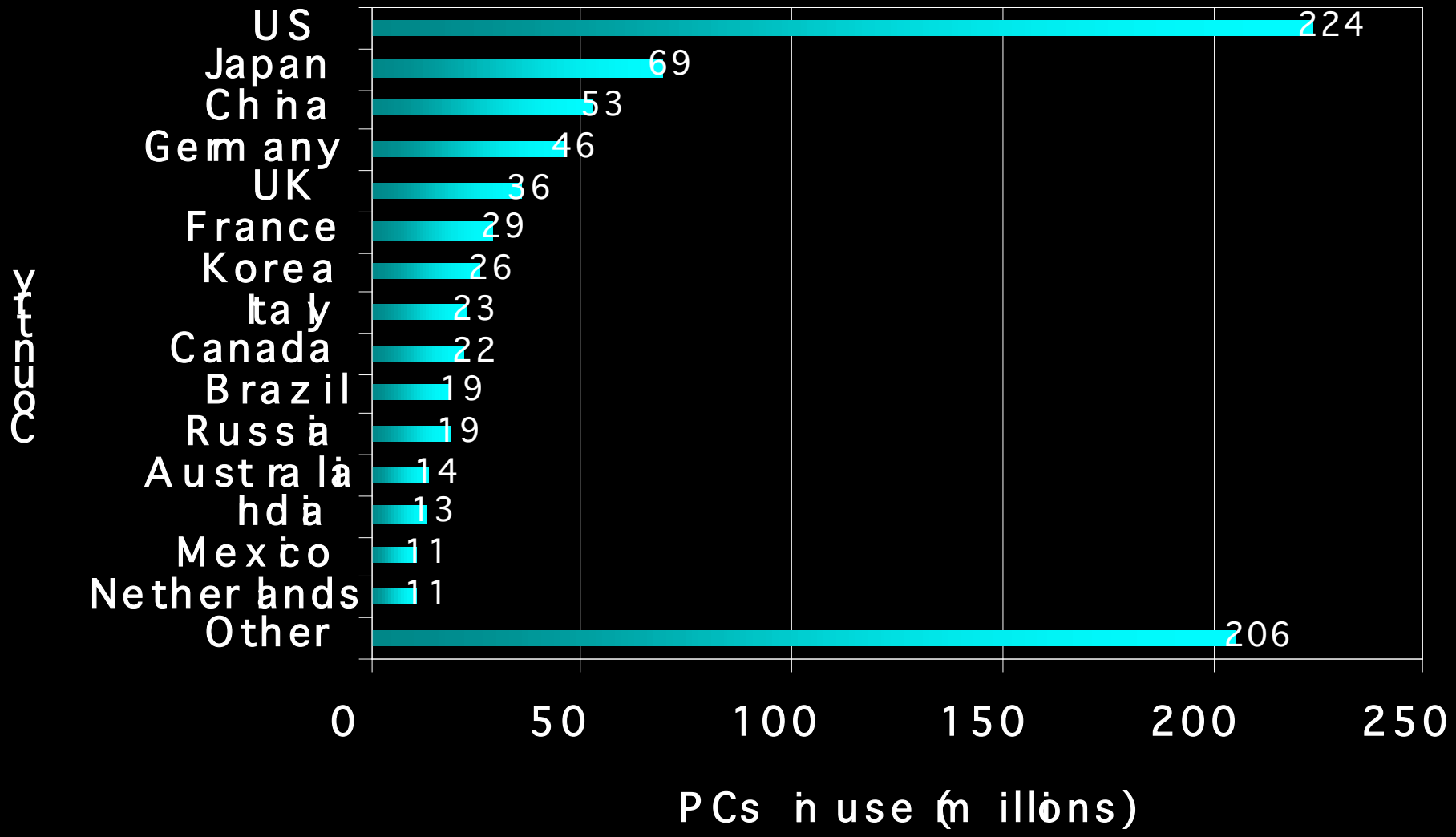

VAIO

“Computers in the future may weigh no more than 1.5 tons.”

a Popular Mechanics editorial

1949

PCs in use worldwide (2004)

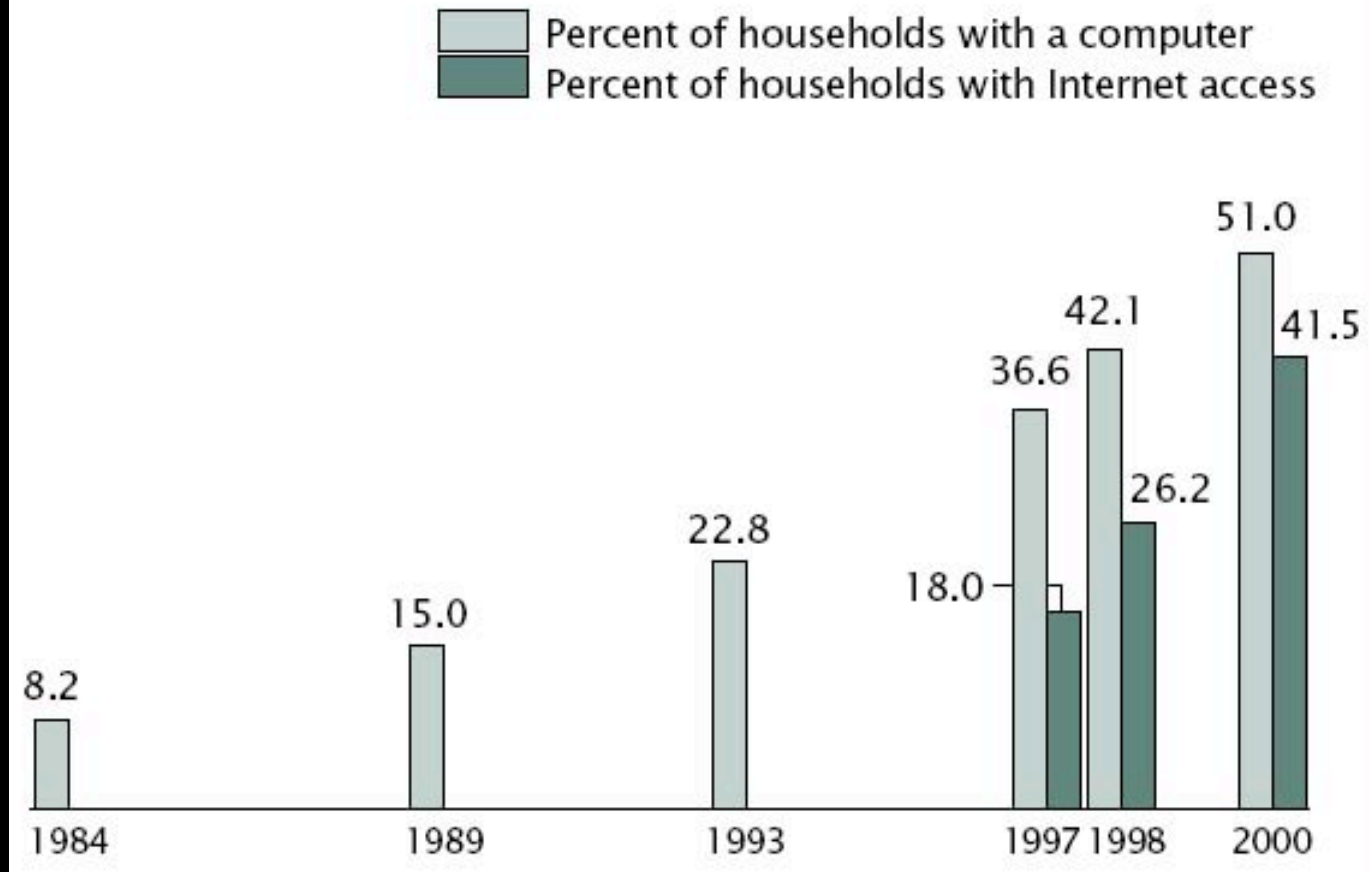


"I think there is a world market
for about five computers”

remark attributed to
Thomas J. Watson
Chairman of the Board
International Business Machines
1943

Computers and Internet Access in the Home: 1984 to 2000

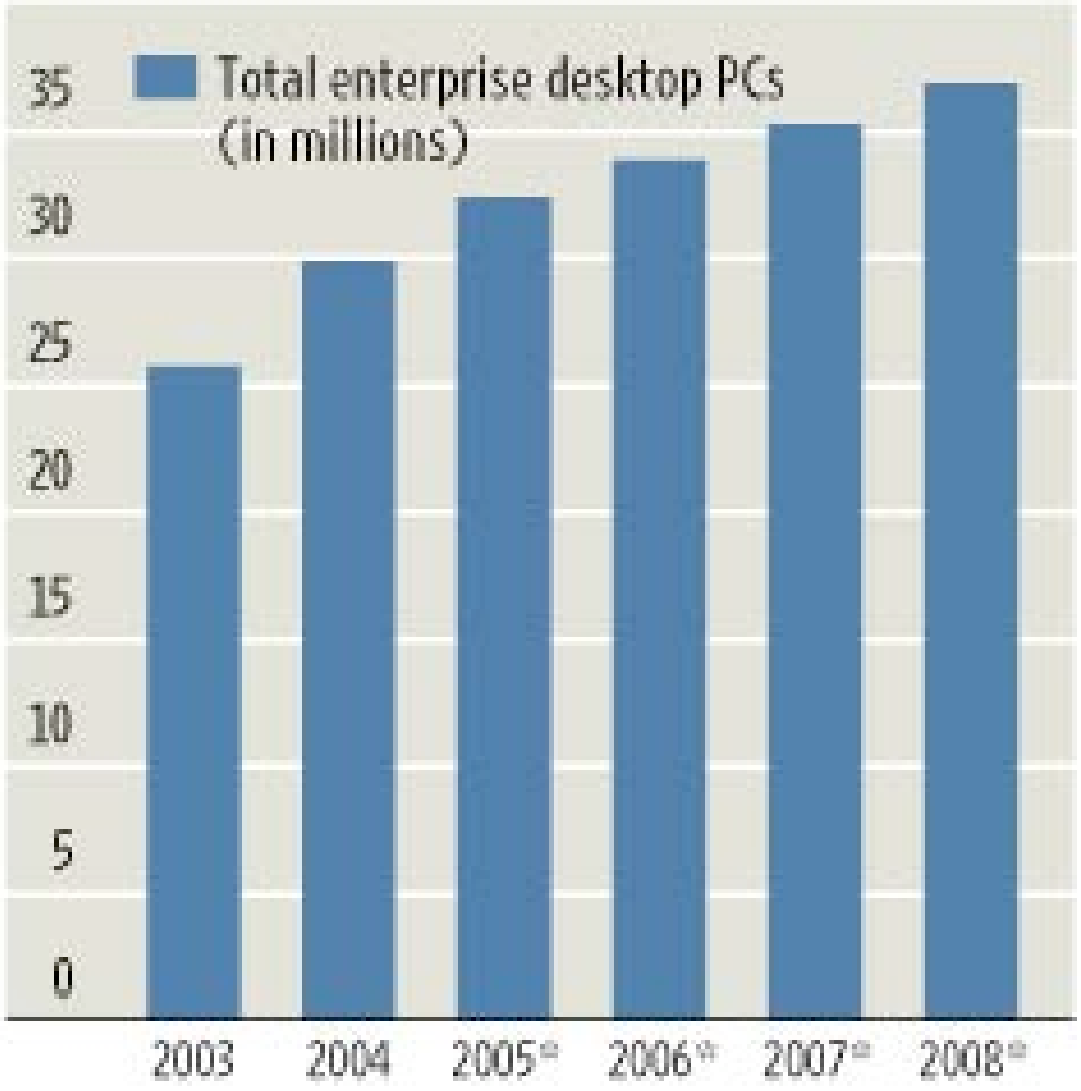
(Civilian noninstitutional population)



Note: Data on Internet access were not collected before 1997.
Source: U.S. Census Bureau, Current Population Survey, various years.

“There is no reason anyone would want a computer in their home.”

Ken Olson
founder and chairman
Digital Equipment
1977

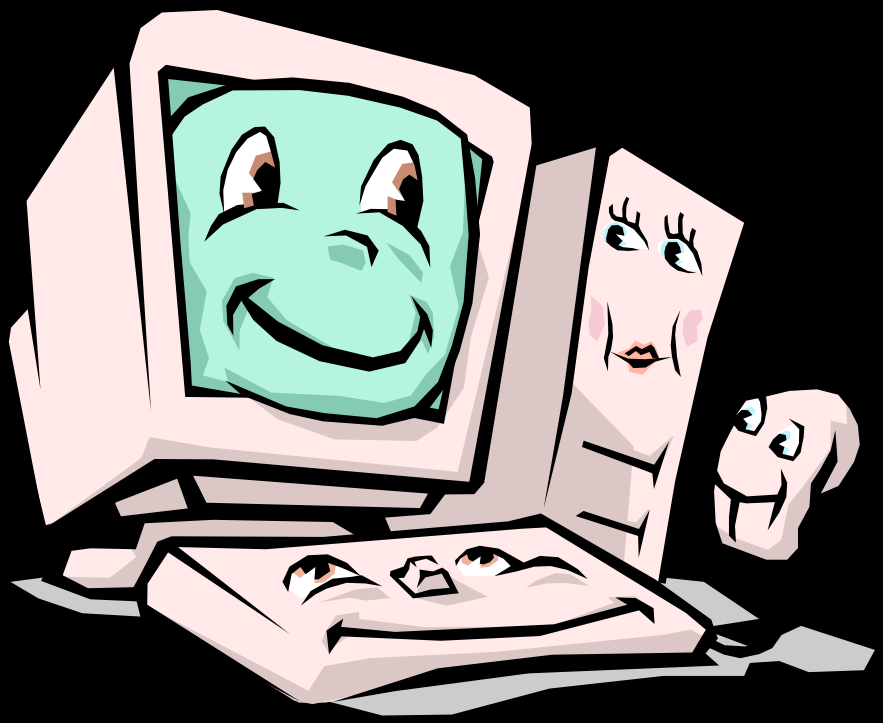

Total enterprise desktop PCs (in millions)
35
30
25
20
15
10
5
0
2003
2004
2005*
2006*
2007*
2008*
* Numbers for 2005 and after are estimates.

“I can assure you that data processing is a fad that won't last out the year.”

a Prentice Hall business book editor

1957

today's computer



today's computer problem

problem #1: manageability

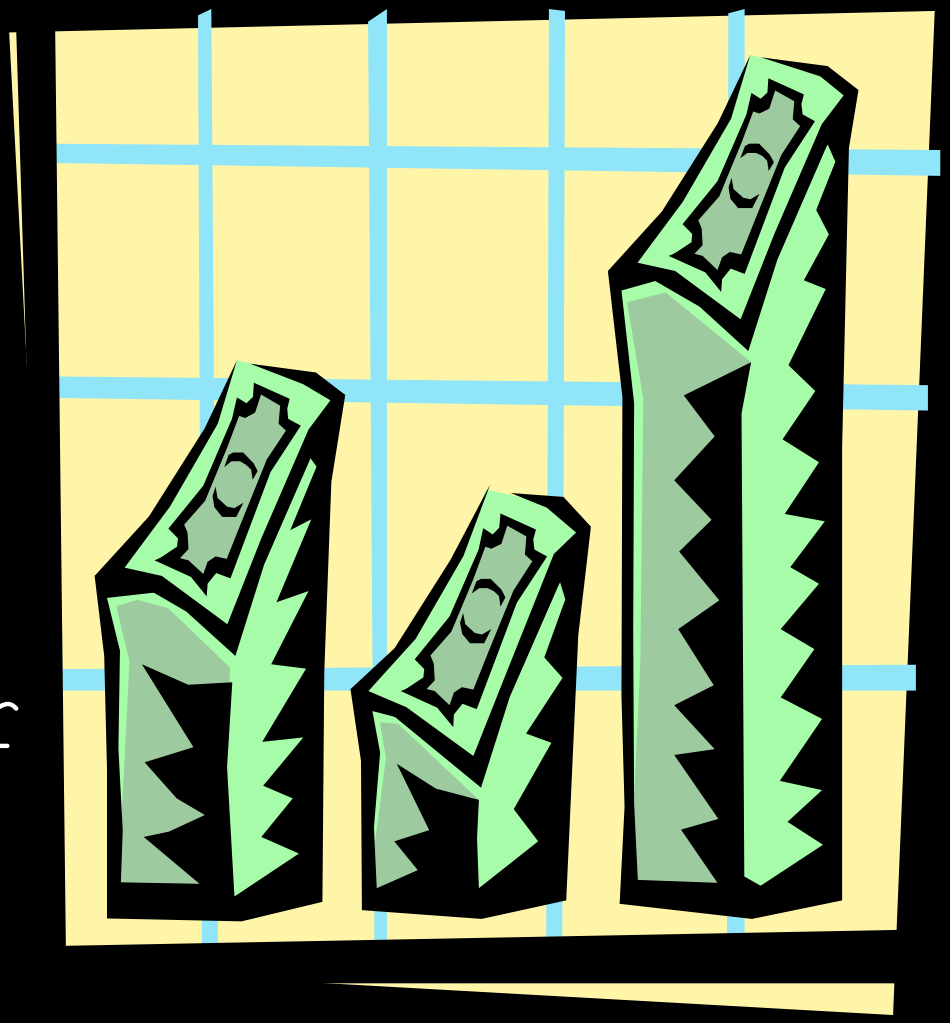
problem #2: operating cost

move

add

change

$1000 per incident

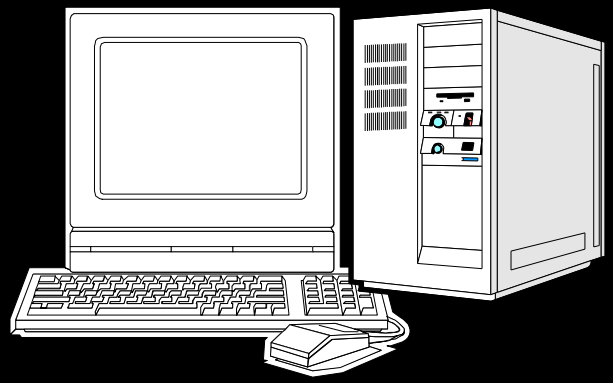


problem #3: availability

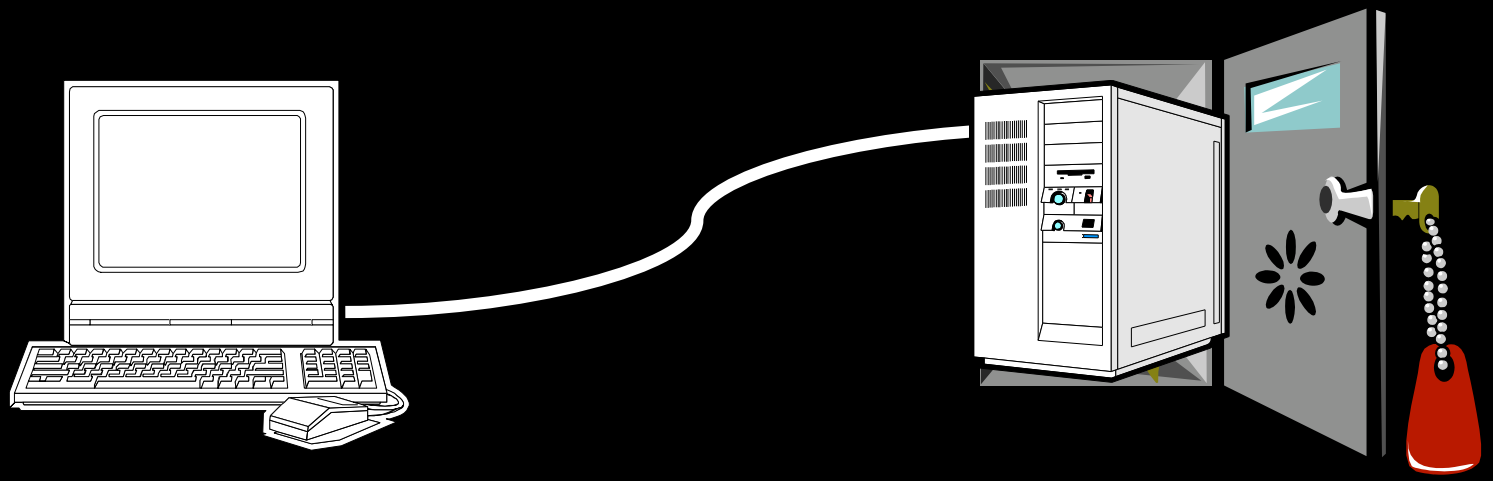
problem #4: work area

problem #5: security

dis-integration of the computer



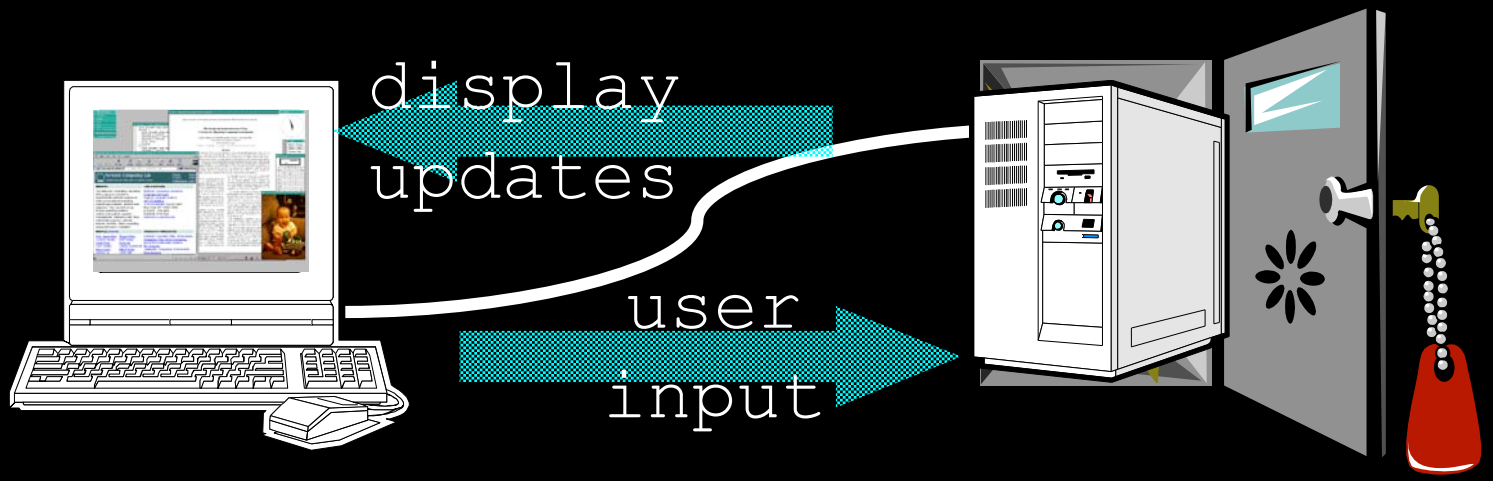
thin-client computing



network decouples computing and display

thin-client computing

application processing
and data here



stateless client

secure server room

benefits

simplify IT management

minimize cost of desktop failures

transparent user mobility

continuous computing access

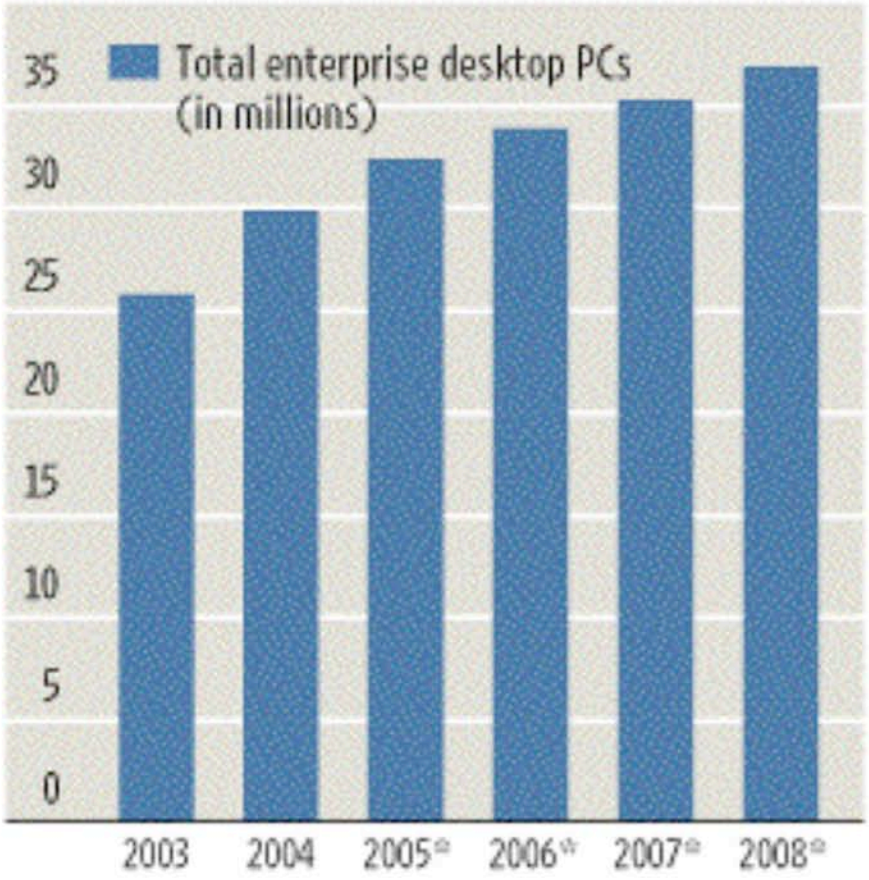
secure computing services

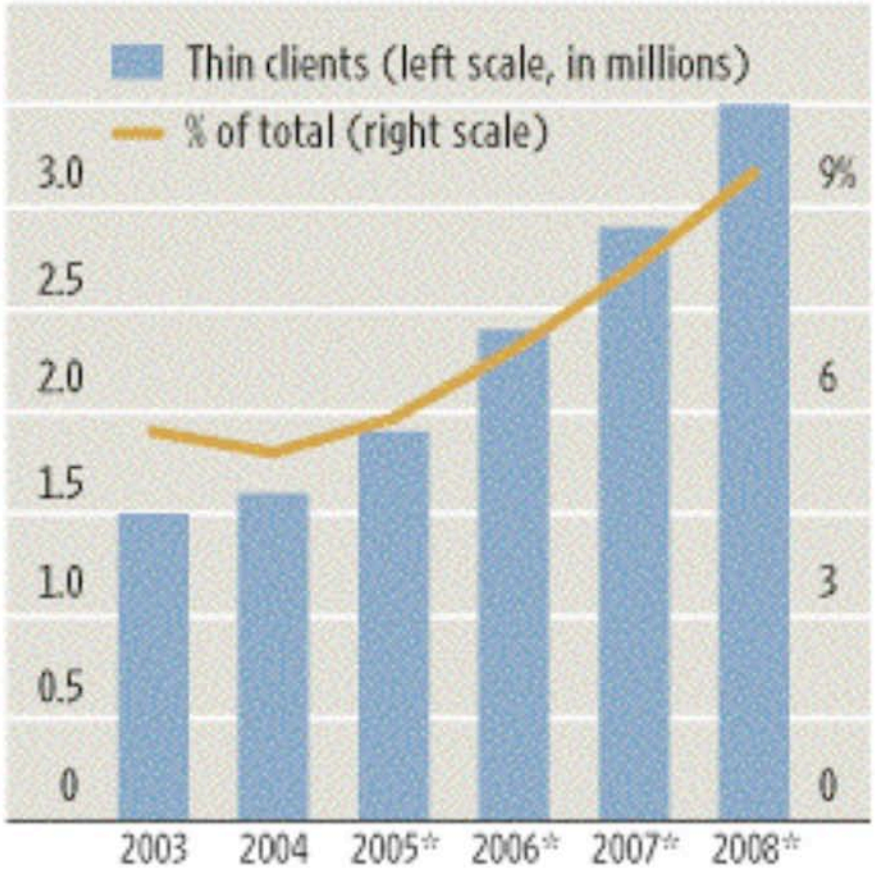
improve user/computer work areas

utilize resources efficiently

The Inside Skinny

"Thin client" computers are expected to gain share among large and medium-size companies (the so-called enterprise desktop market).

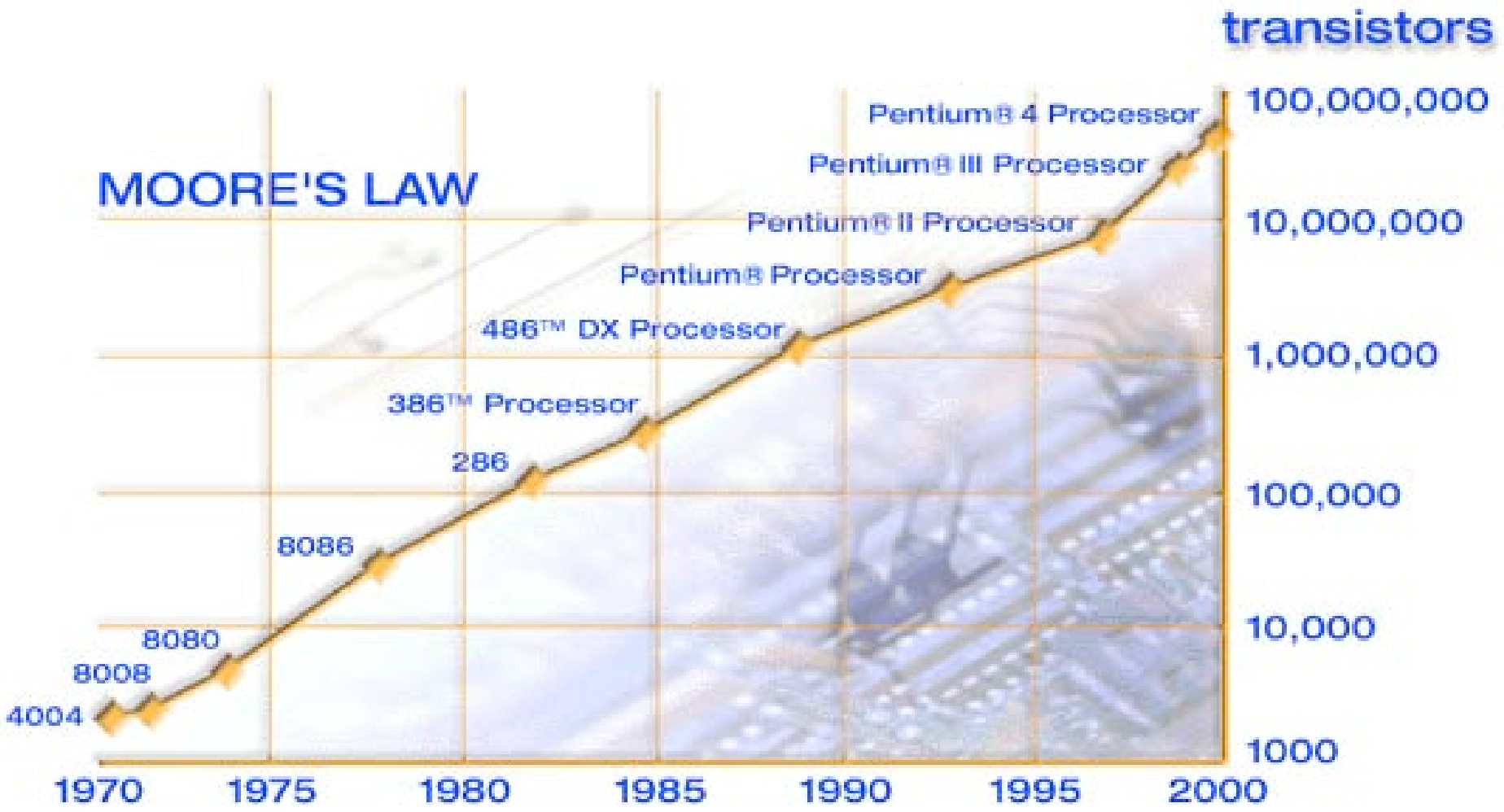




* Numbers for 2005 and after are estimates.

Source: IDC

trends

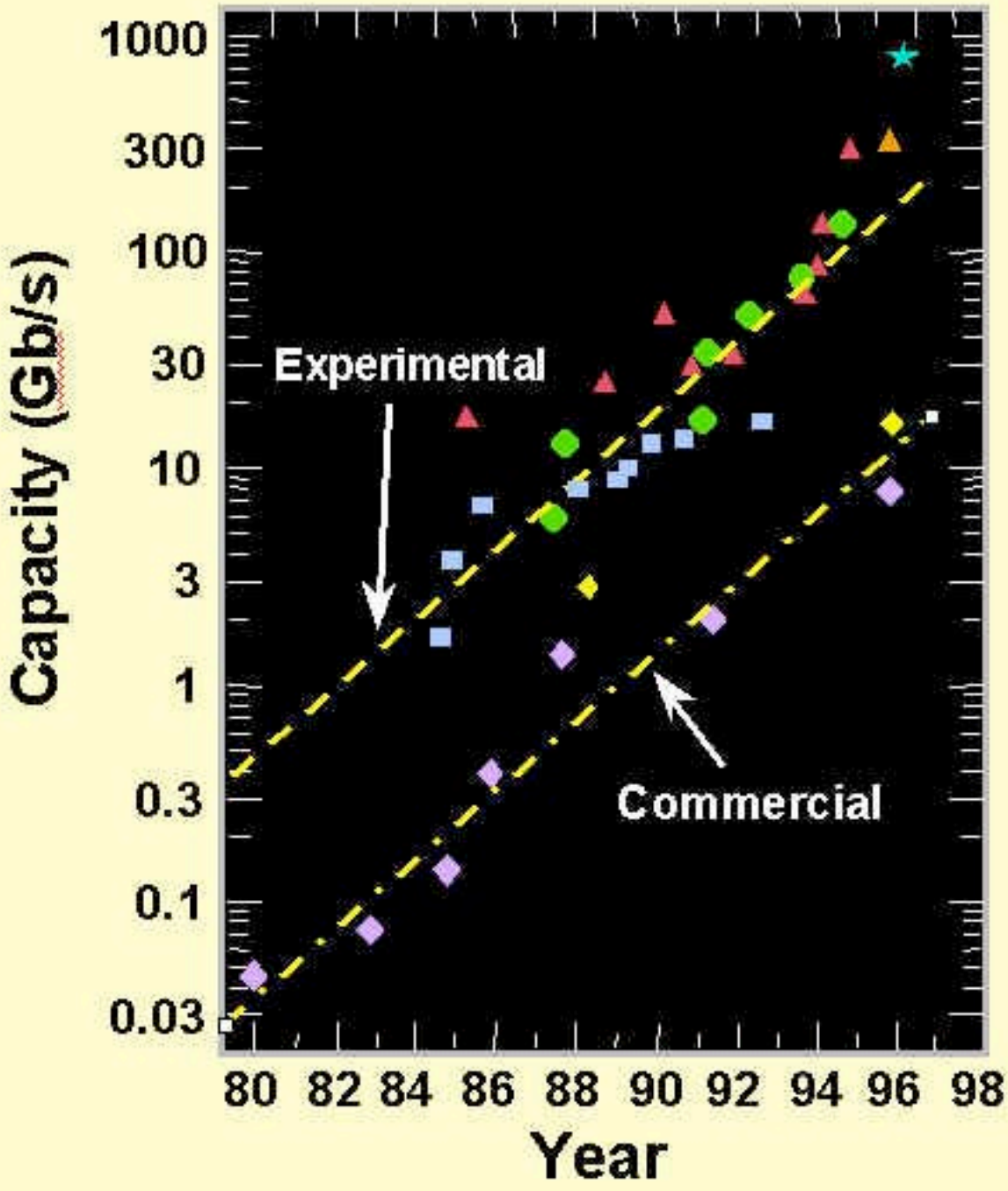

transistors
MOORE'S LAW
Pentium® 4 Processor
Pentium® III Processor
Pentium® II Processor
Pentium® Processor
486™ DX Processor
386™ Processor
286
8086
8080
8008
4004
100,000,000
10,000,000
1,000,000
100,000
10,000
1000
1970
1975
1980
1985
1990
1995
2000

computers are cheap

people are expensive

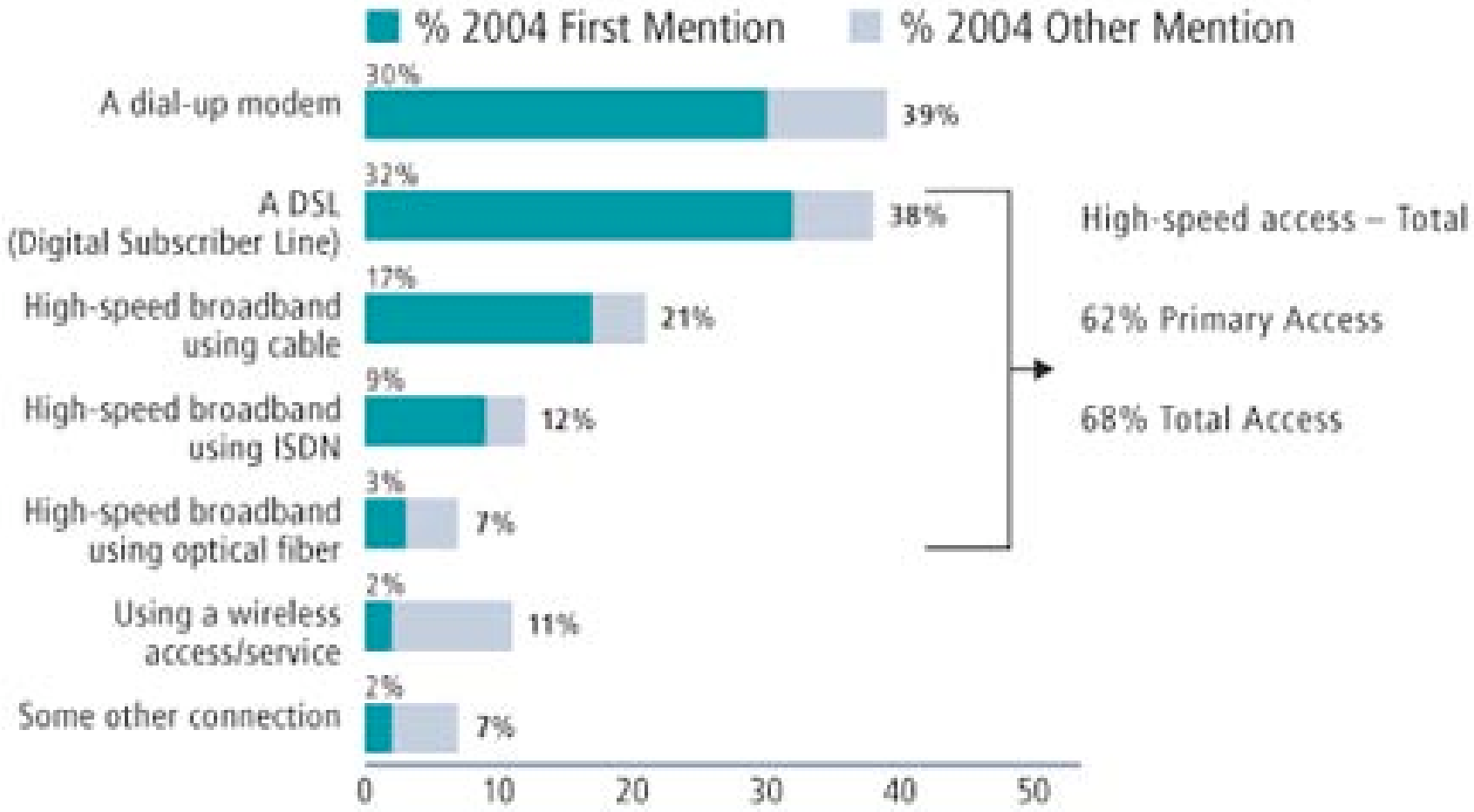
computers vs people

Dell Dimension 2400 PC desktop, 2.4 GHz CPU, $420	move, add, change: $1000 per incident
Dell PowerEdge 420 server, 2.4 GHz CPU, $350	


Capacity (Gb/s)
1000
300
100
30
10
3
1
0.3
0.1
0.03
Experimental
Commercial
80
82
84
86
88
90
92
94
96
98
Year

2004: Percent of Adult Internet Users – Past 30 Days

Used the Following as Primary and Secondary Internet Connection



Past 30 Day Internet Users

Source: Ipsos-Insight, *The Face of the Web 2004*, survey of 6,544 adults in 12 global markets, October 2004

Internet to Be 50 Times Faster by 2010

By Kim Tae-gyu
Staff Reporter

Korean people will be able to enjoy the Internet at the speed of up to 100 Mbps by 2010, around 50 times faster than now, thanks to the up-and-coming Broadband convergence Network (BcN).

The Ministry of Information and Communication (MIC) on Tuesday said it selected three consortiums for trial operations of the BcN services, or the Korean equivalent to the next-generation network.

The BcN will integrate traditionally separated telecom, Internet and broadcasting lines into a single network while seamlessly switching over wired and wireless connection.

Hand-in-hand with such top-line network infrastructure, an array of futuristic features are expected to arrive including voice over Internet protocol, T-commerce, IP-TV and video on demands at reasonable prices.

The integrated network has been regarded as a minimum must in enabling a future mega trend of digital convergence, which breaks barriers between differing businesses up until now.

The nation's telecom juggernauts have dogged the all-out efforts to jump onto the lucrative BcN bandwagon and a total of four consortiums applied for the licenses for trial operations last month.

Among them, three headed each by KT, SK Telecom and Dacom were officially entitled to set up backbone and subscriber networks for the BcN from next year.

As soon as the networks are established, the companies plan to sign up subscribers


http://100x100network.org - The 100x100 Project - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Charting a path to 100 Mbps access from 100 Million homes
100 x 100
The Project
Mission
FAQ
Background
Participants
Researchers
Institutions
Internal site
Communications
News Room
Papers
hzhang@cs.cmu.edu
Over the past 100 years, the telephone has grown from a rare communications device of the wealthy to a ubiquitous implement that has streamlined the processes of the economy. Similarly, the Internet began 30 years ago as a research network connecting a handful of research centers over extremely expensive long distance data lines. The past 10 years have established the value of data connectivity to the homes of average Americans, with 50% of homes now having a modem connection or better. Today, both economists and policy makers have recognized the economic importance of digital connectivity, and technologists are searching for viable ways to transition the Internet from a network of research centers to a ubiquitous service akin to the telephone.
This rebuild presents an emerging opportunity to create the first nationwide communications infrastructure designed from first principles to bring reliable and private Internet service to consumers and small businesses across the country. The 100x100 project, funded by the National Science Foundation's Information Technology Research program, is working to conduct the basic research and develop the blueprint designs that will guide decision-makers in the construction of a network that is dependable and secure; understandable to users and operators; and both economical and scalable.
AT&T
Berkeley
Carnegie Mellon
Fraser Research
INTERNET
RICE
Done
Internet

“the network is the computer”

thin clients vs mainframes

rich graphical interfaces	dumb plain text terminals
clusters of inexpensive servers, blades	large, expensive machine

Firefox - Rediscover the web - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Address http://www.mozilla.org/products/firefox/

mozilla

search mozilla: Go

Products | Support | Store | Developers | About

Firefox

rediscover the web

The wait is over. Firefox empowers you to browse faster, more safely and more efficiently than with any other browser. Join more than **44 million** others and make the switch today — Firefox imports your Favorites, settings and other information, so you have nothing to lose.

Free Download

Firefox 1.0.2 for Windows, English (4.7MB)
Other Systems and Languages

Or, get the Firefox CD & Guidebook from the Mozilla Store.

- System Requirements
- Release Notes
- Other Contributed Builds

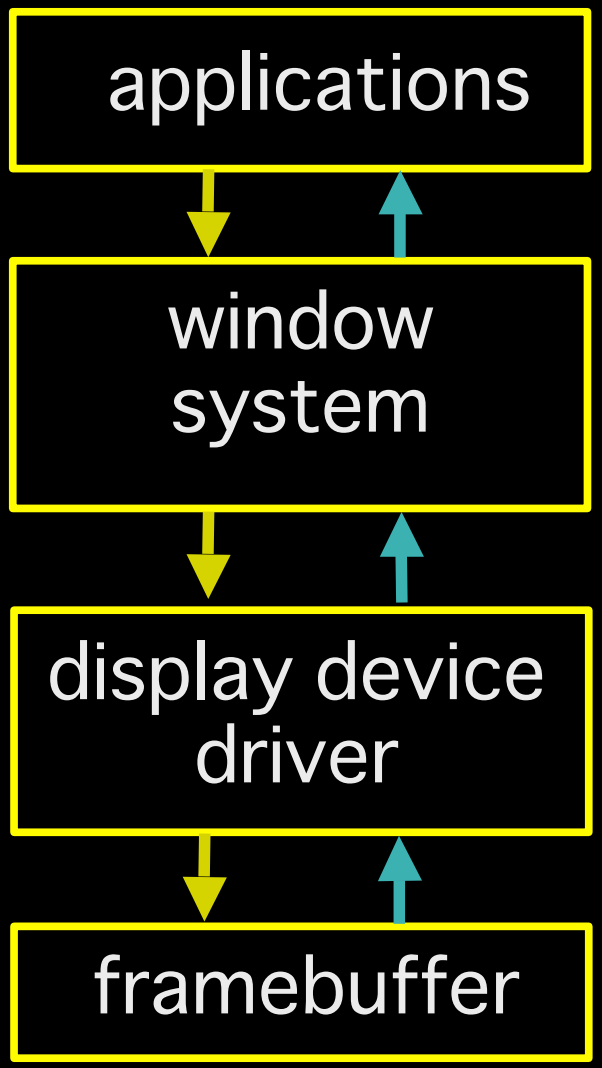
thin clients vs web

preserve software investments	rewrite applications for the web
no client applications	client browser and helper applications

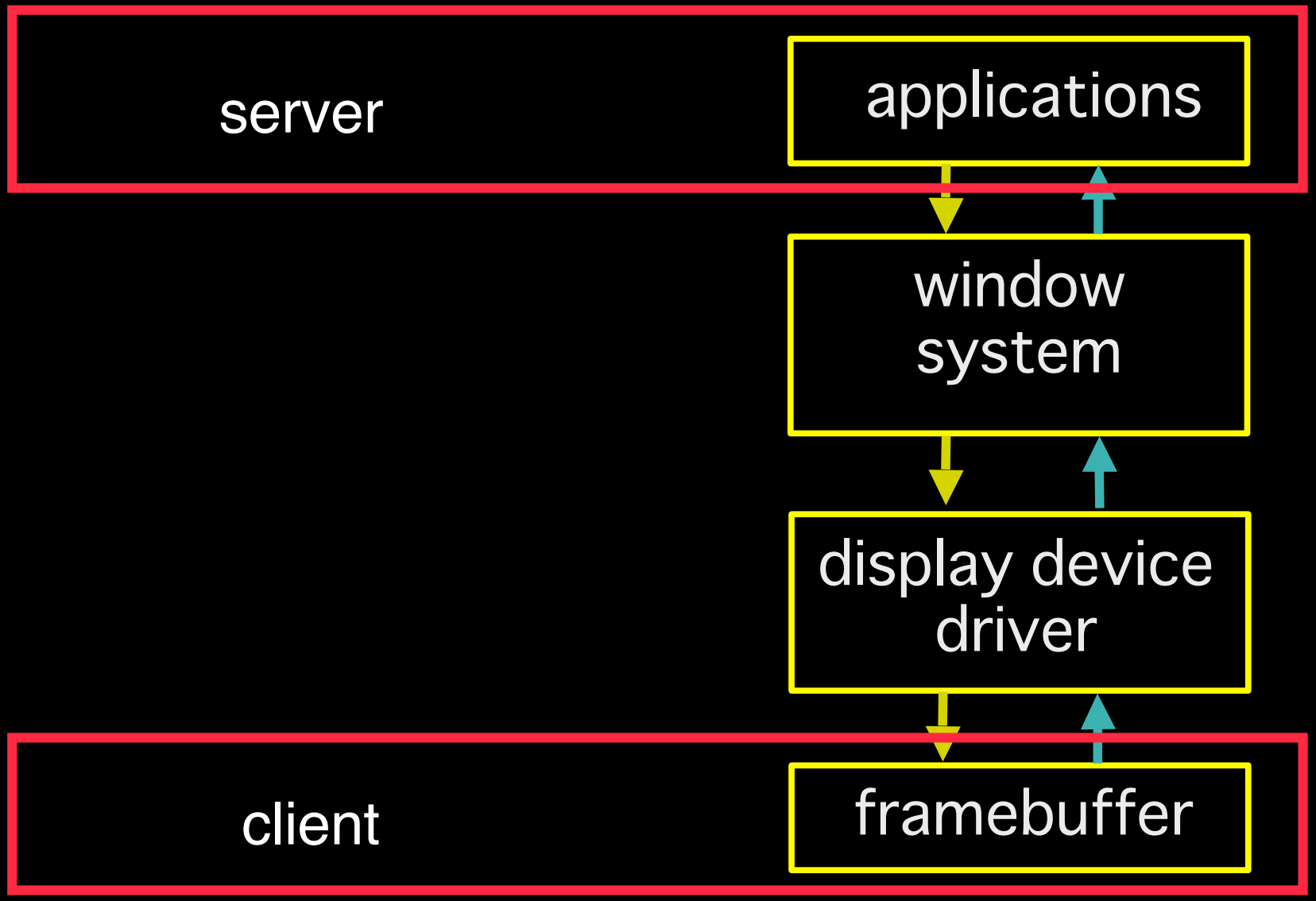
key technologies

remote display

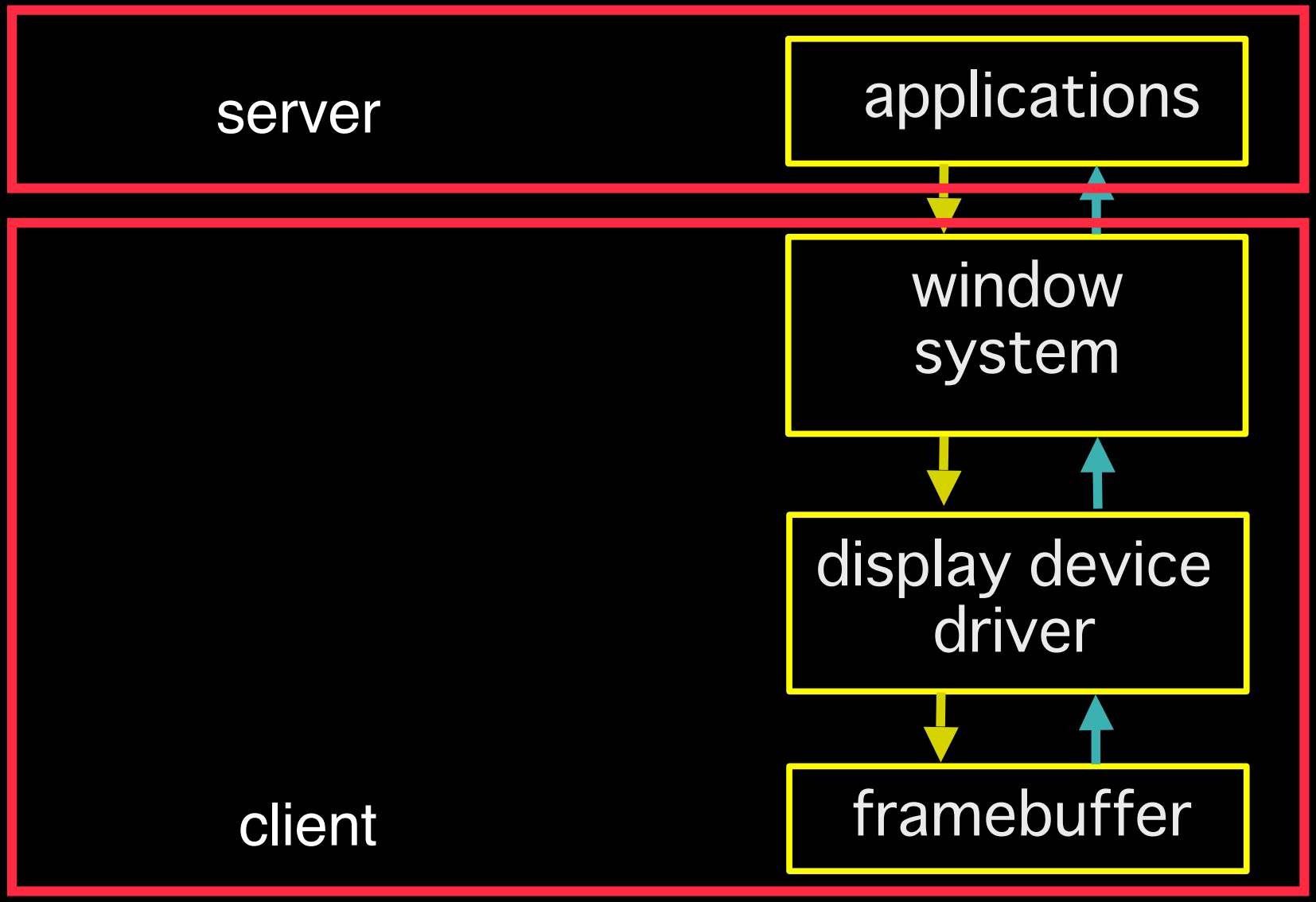
display pipeline



client/server partitioning



window server on client



window server on client

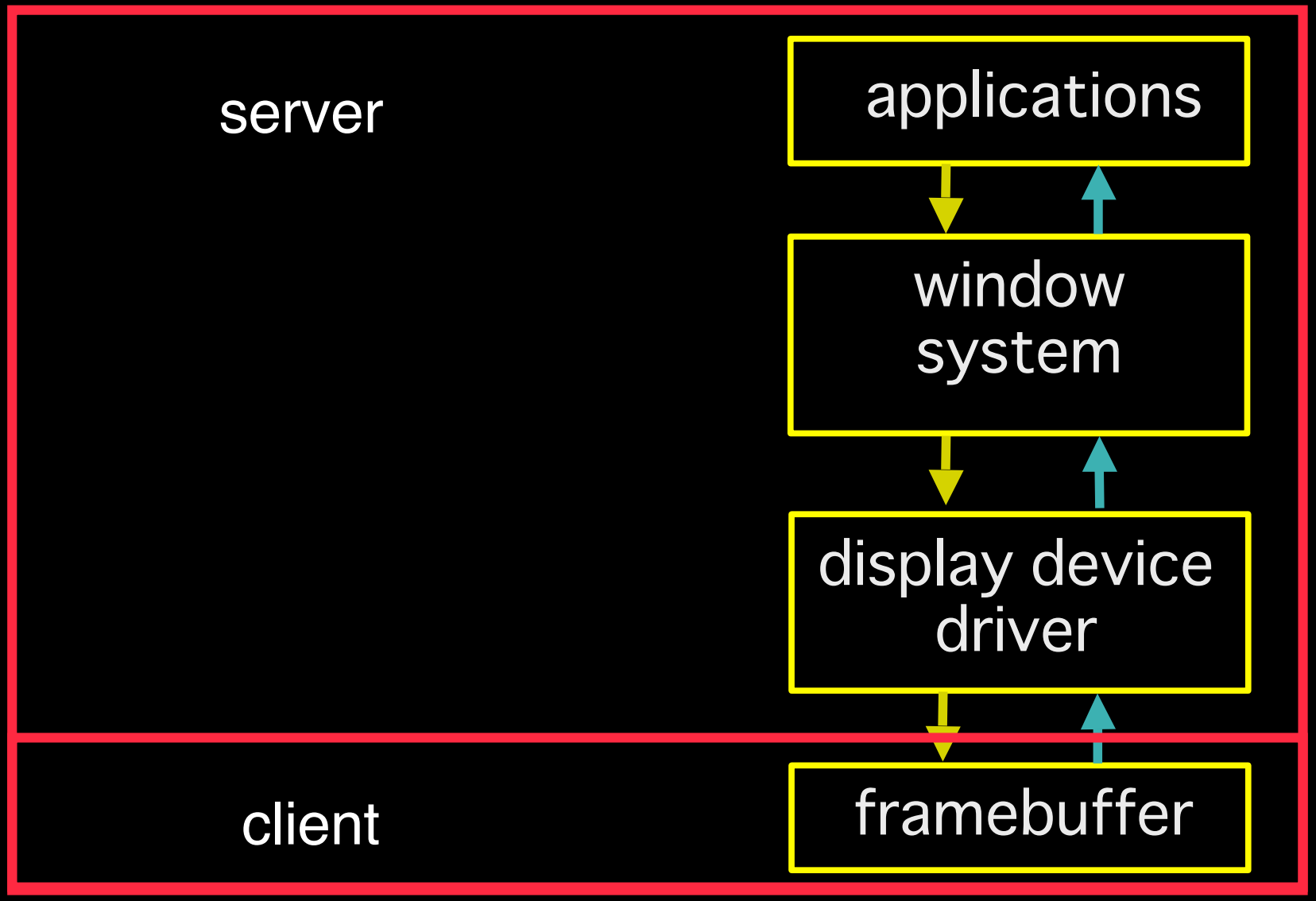
local non-app UI interactions

complex software running on client

software needs to be maintained

client resources need to scale

window server on server



window server on server

no complex client software

no client software maintenance

client scales with display

“ultra-thin” client

wire protocol

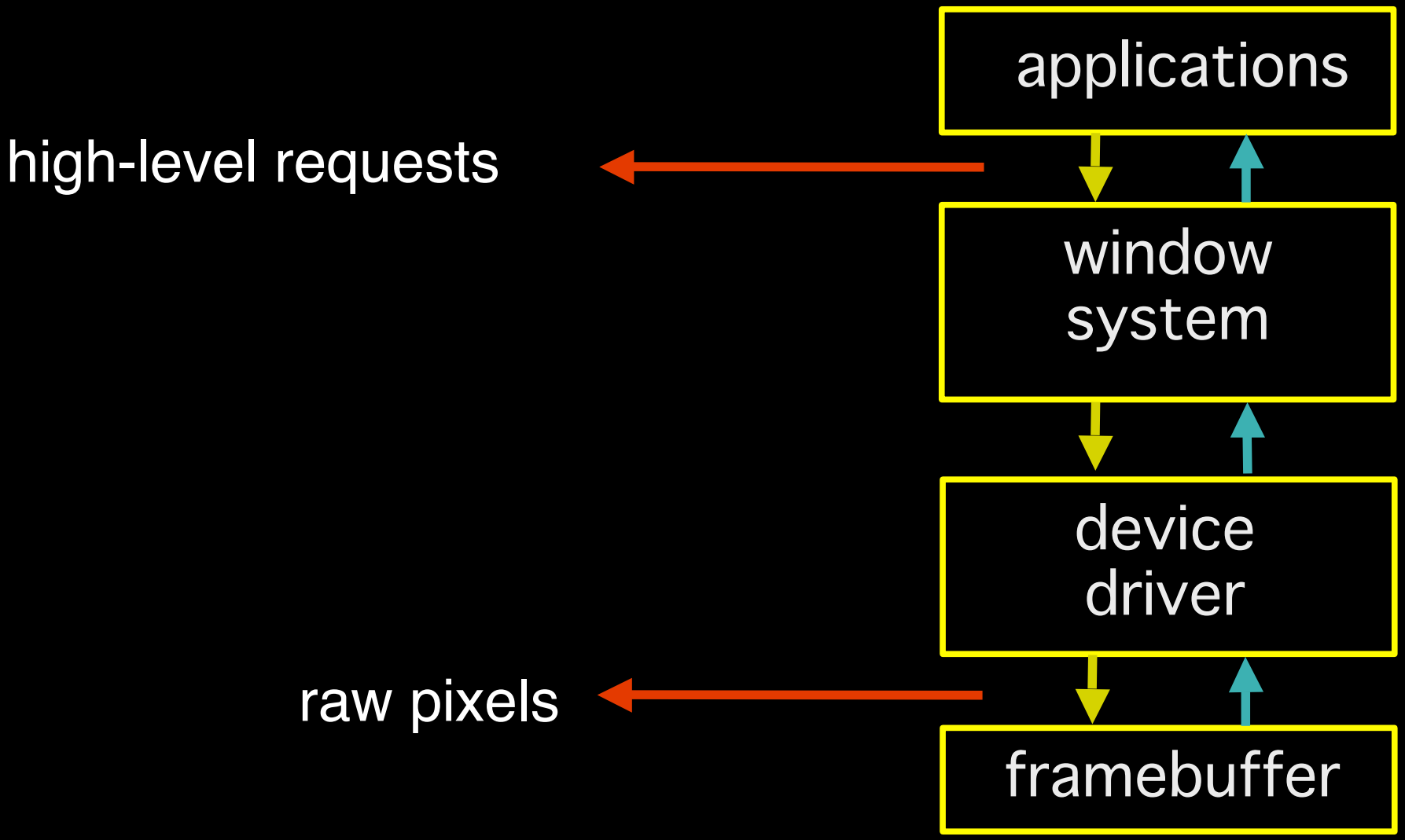
high-level graphics

low-level graphics

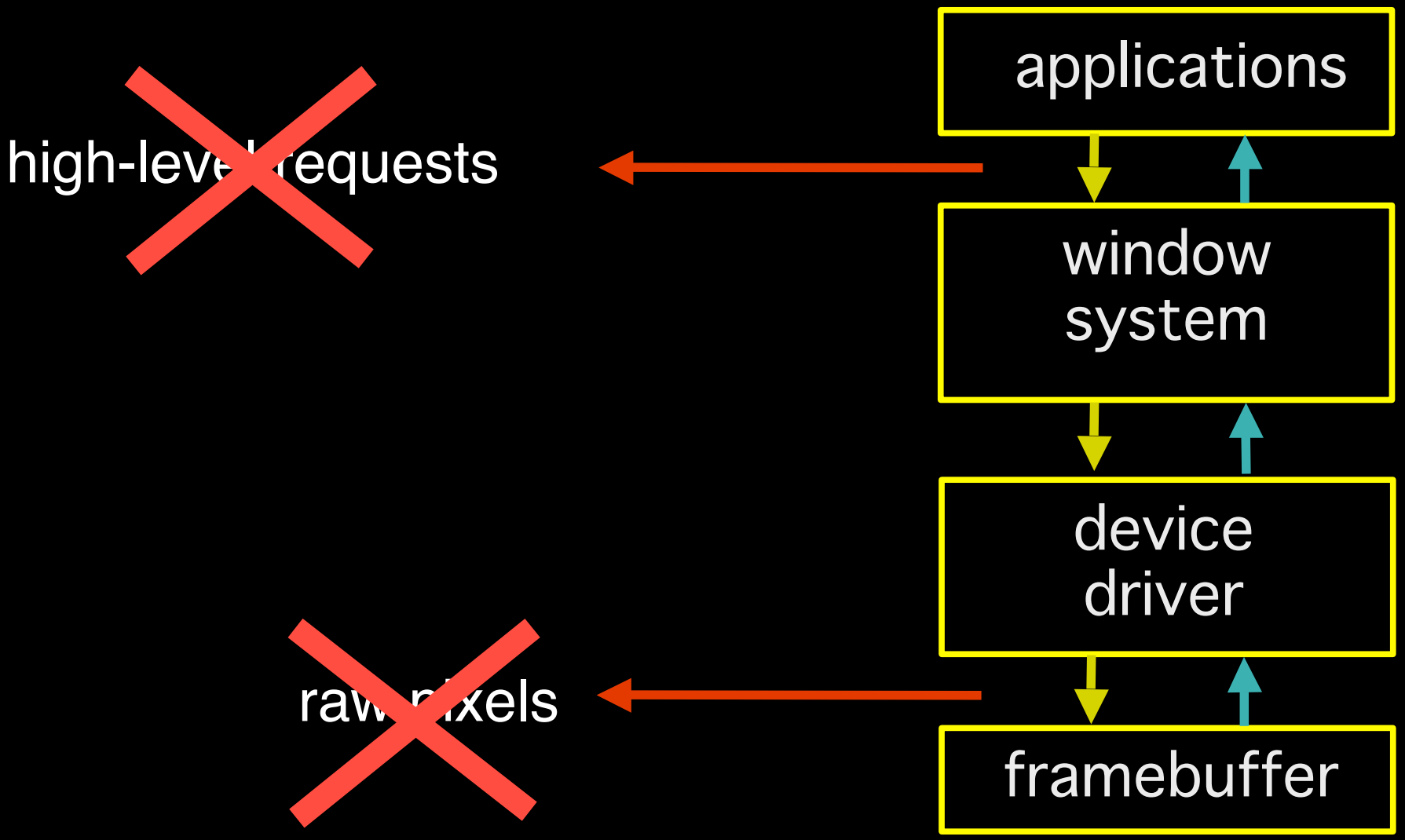
2D drawing primitives

raw pixels

application → protocol



THINC


high-level requests
raw pixels
applications
window system
device driver
framebuffer

THINC

display updates

input events

applications

window system

virtual device driver

THINC protocol

copy

solid fill

pixmap fill

bitmap

RAW

THINC optimizations

offscreen drawing

transparent video support

local cursor drawing support

server-push model

smallest update first scheduling

server-side screen scaling

enables

stateless clients

heterogeneous display devices

remote access

remote collaboration

performance?

CITRIX

REAL VNC

Microsoft Windows xp

GoToMyPC

NOMACHINE

BUILDING THE NETWORK COMPUTING ON THE POWER OF X

The XFree86 Project, Inc.™

name	custom window server	ultra thin	color depth	audio	en-cryption	OS
local PC	no	N/A	24	yes	N/A	Linux
ICA	no	yes	24	yes	yes	Windows
RDP	no	yes	24	yes	yes	Windows
GoToMyPC	no	yes	8	no	yes	Windows
X	no	yes	24	yes	no	Linux
X ssh -C	no	no	24	yes	yes	Linux
NX	no	no	24	yes	yes	Linux
VNC	yes	yes	24	no	no	Linux
Sun Ray	yes	yes	24	yes	yes	Linux
THINC	no	yes	24	yes	yes	Linux

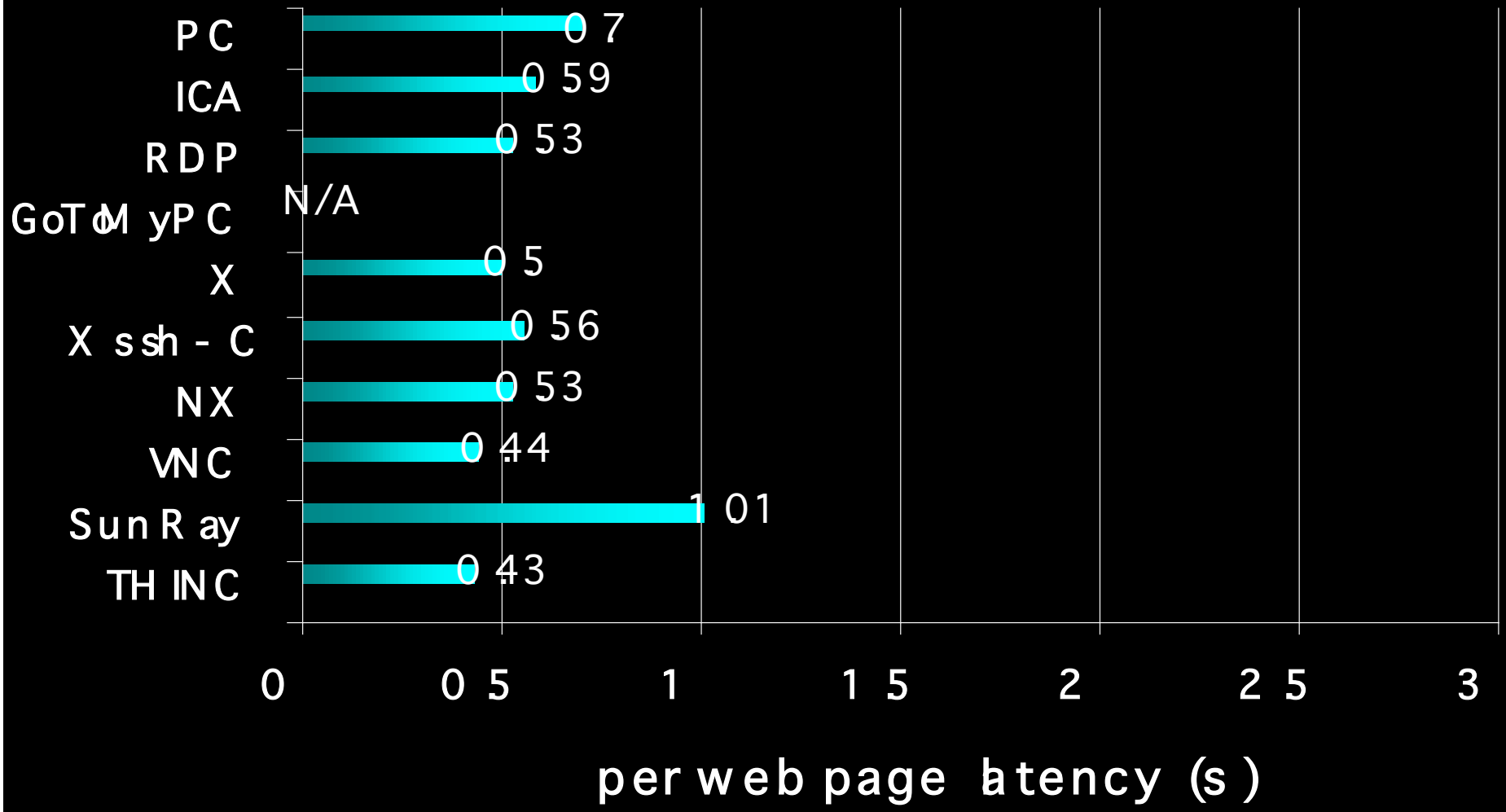
configurations

desktop LAN

desktop WAN

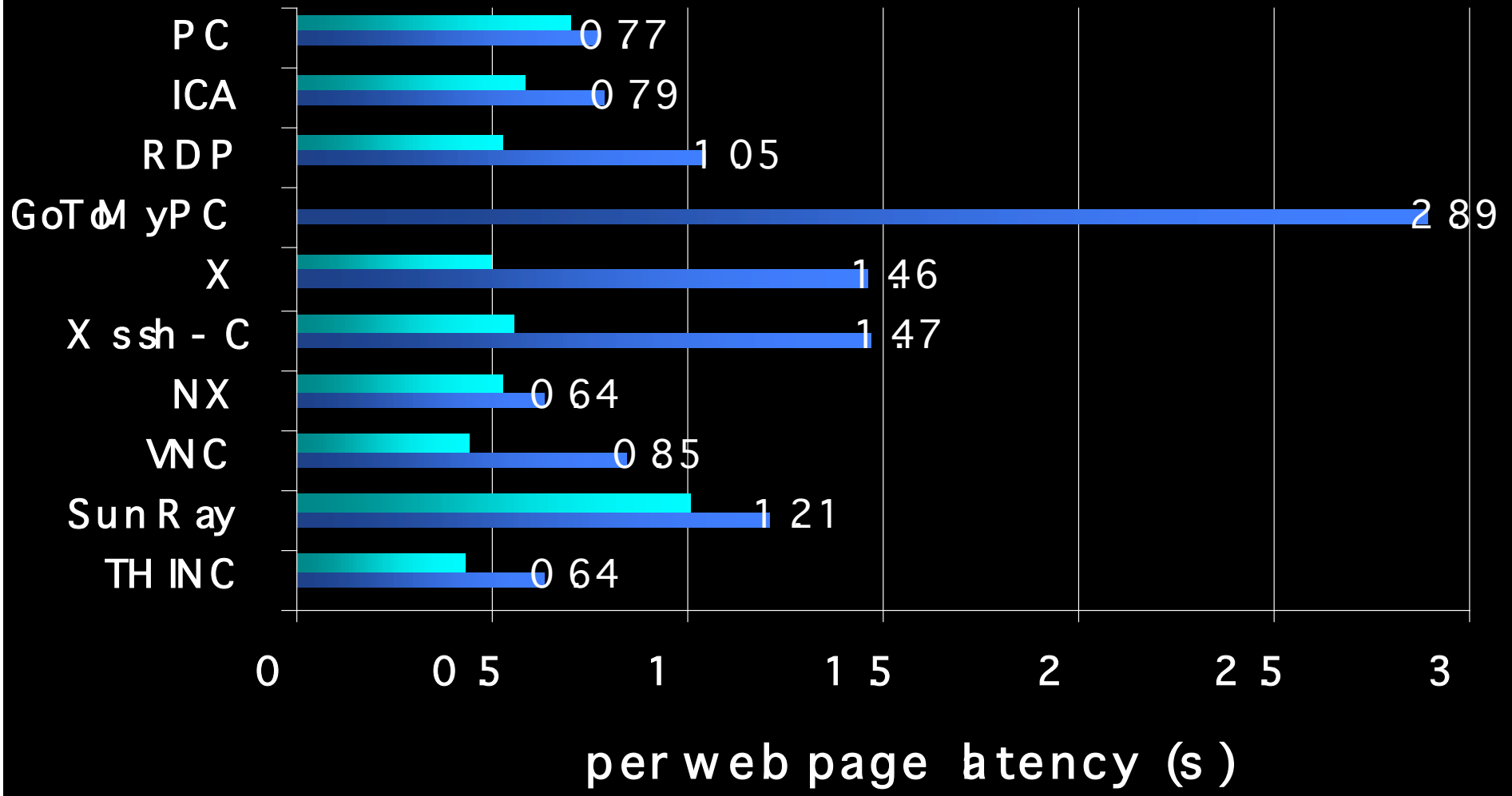
802.11g PDA

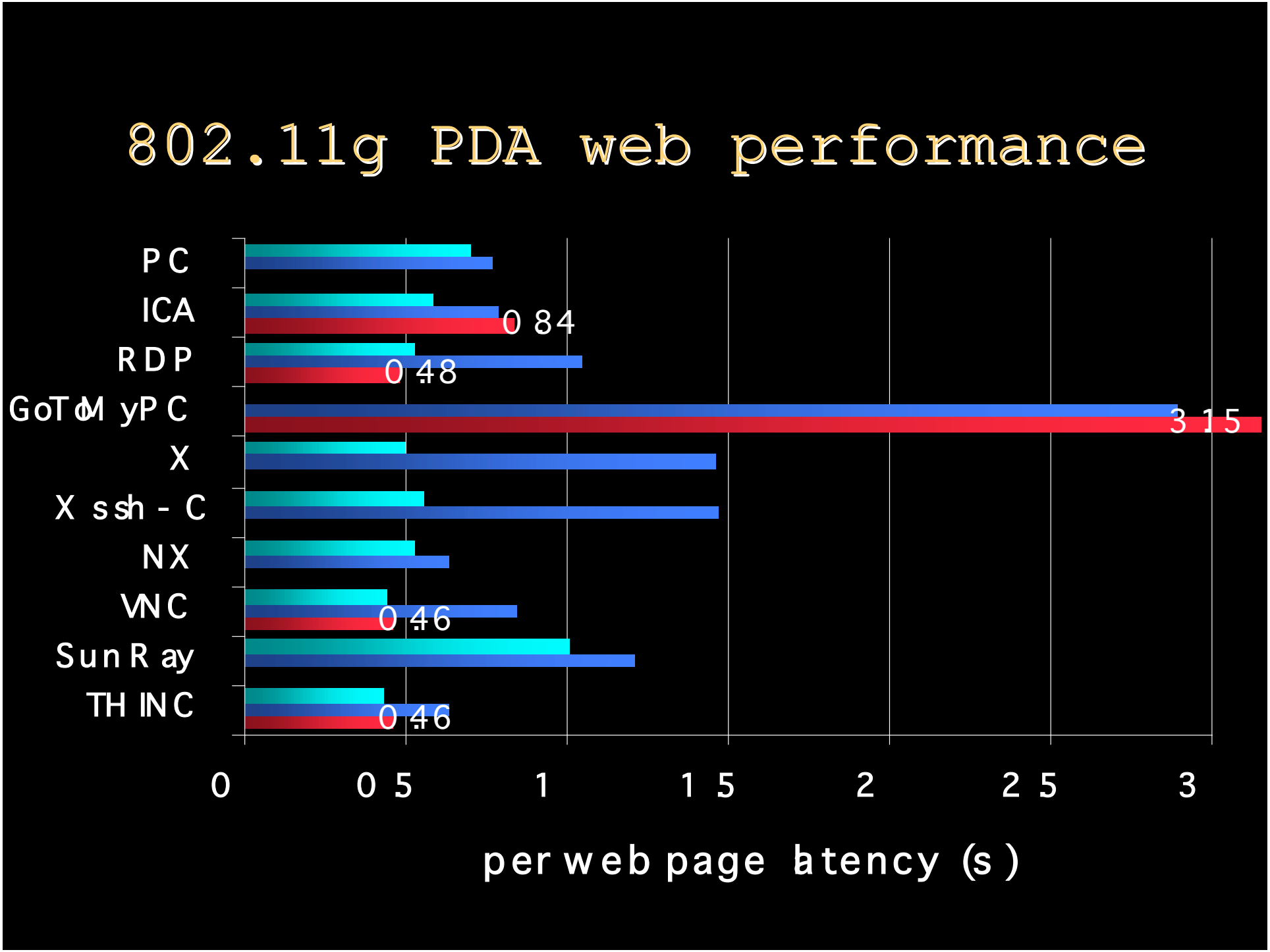
desktop LAN web performance



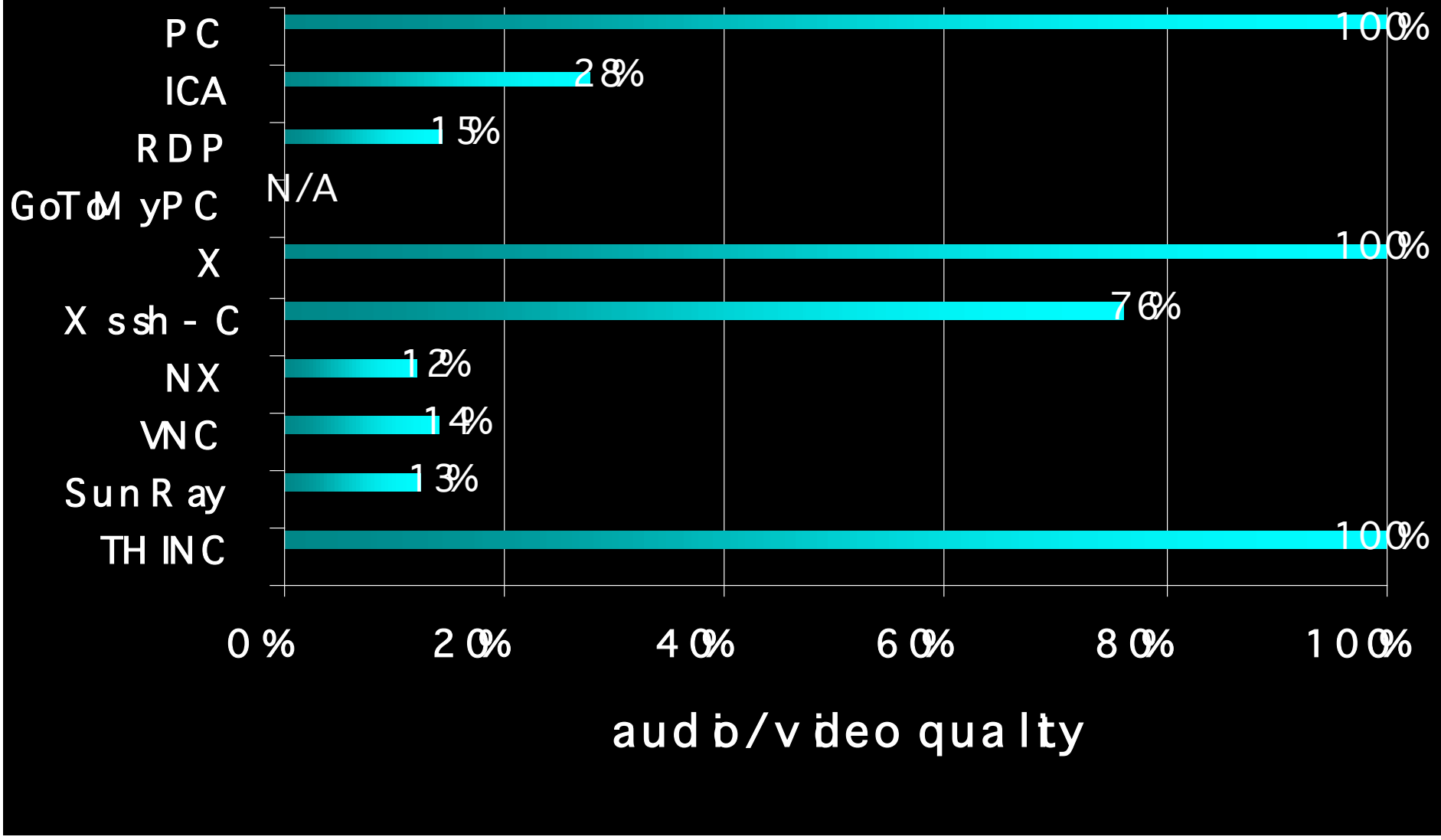
desktop LAN web performance

desktop WAN web performance

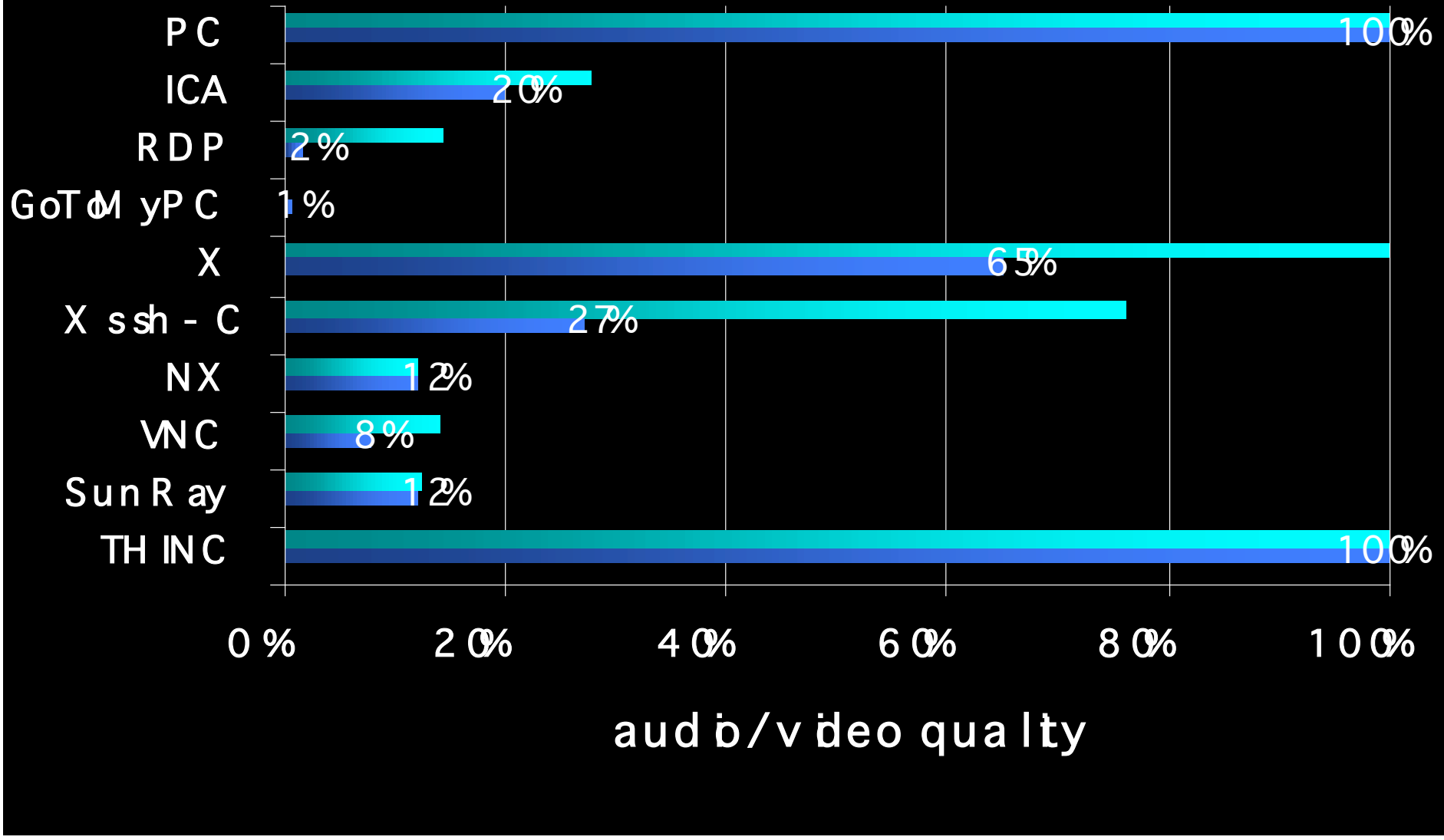



802.11g PDA web performance
PC
ICA
RDP
GoToMyPC
X
X ssh -C
NX
VNC
Sun Ray
THINC
0.84
0.48
3.15
0.46
0.46
0
0.5
1
1.5
2
2.5
3
per web page latency (s)

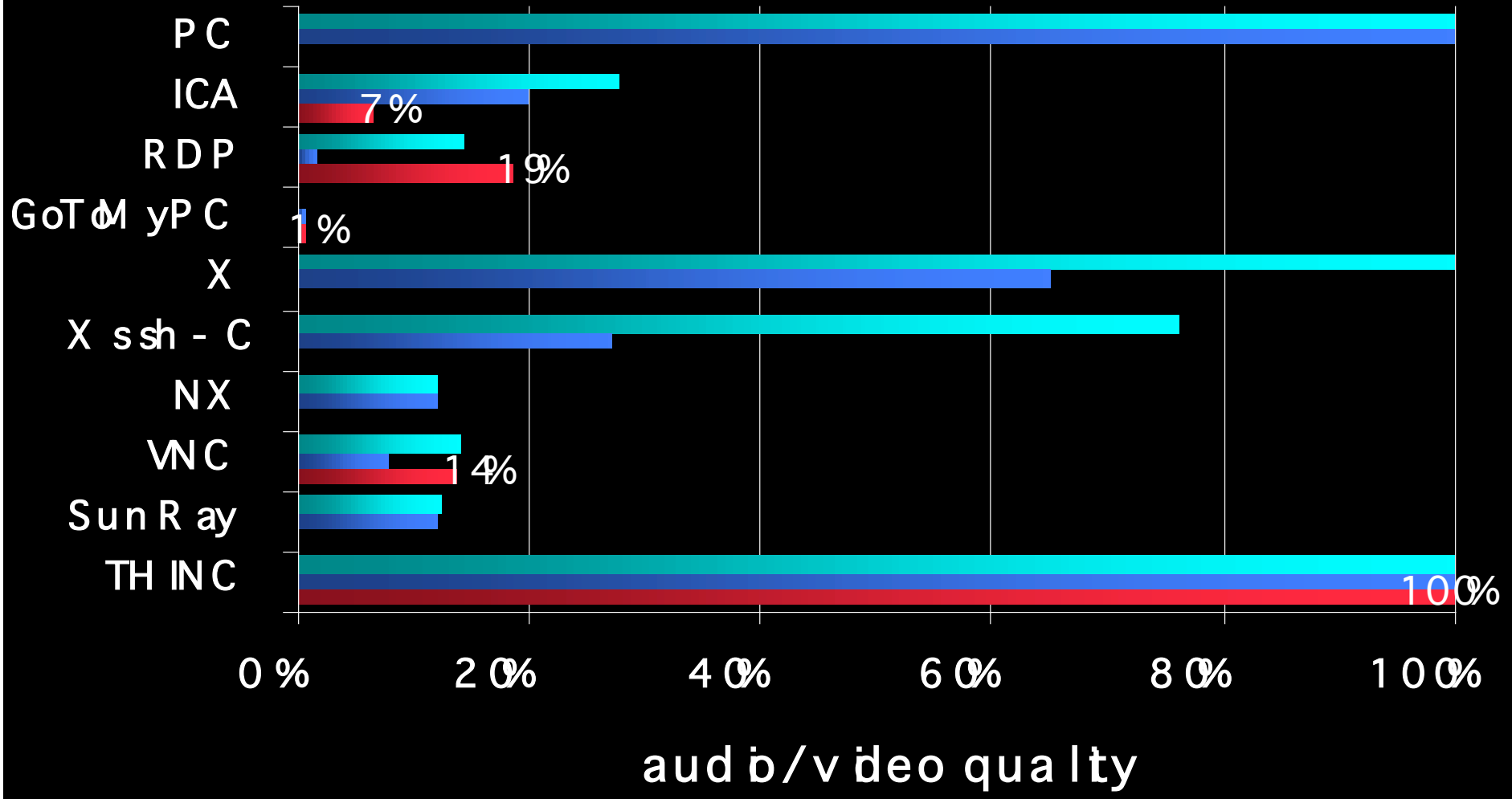
desktop LAN A/V performance



desktop WAN A/V performance



802.11g PDA A/V performance



thinc

ultra-thin client

leverage and virtualize standard display driver interface

fast, lightweight

full-motion, full resolution audio/video performance

transparent
checkpoint/migration

checkpoint

capture the state of a running process and save it so that it can be resumed at a later time

migration

move checkpointed process state to a target machine and resume process

transparent

no application changes

no need for new languages/run-time

no operating system kernel changes

no constraints on use of OS services

enables

software mobility

load balancing

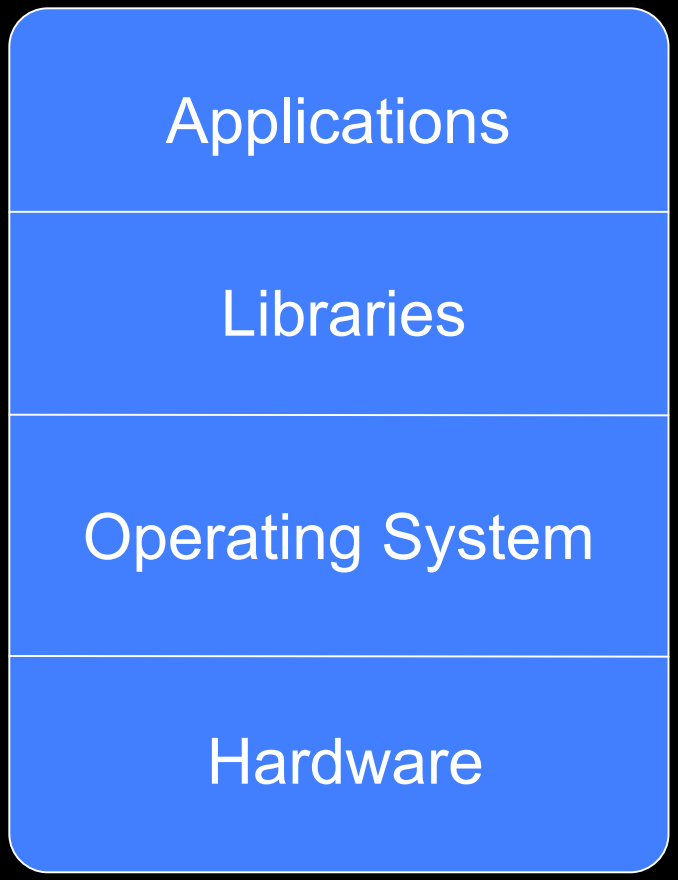
power management

fault resilience

improved system availability

approaches

language	Emerald
library	Condor
kernel	Mosix
hardware	Vmware, Xen
system call	zap



zap

virtualize OS to decouple applications from underlying OS instance

use high-level kernel functionality for portable migration

preserve application availability across operating system upgrades

problem

```
int iChildPID;

if (iChildPID=fork()) {
  /* parent does some work */
  waitpid(iChildPID);
} else {
  /* child does some work */
  exit(0);
}
```

issues

resource consistency

resource conflicts

resource dependencies

transparency

solution

private virtual namespace

PrOcess Domain (POD)

POD virtualization

PID

IPC

file system

network

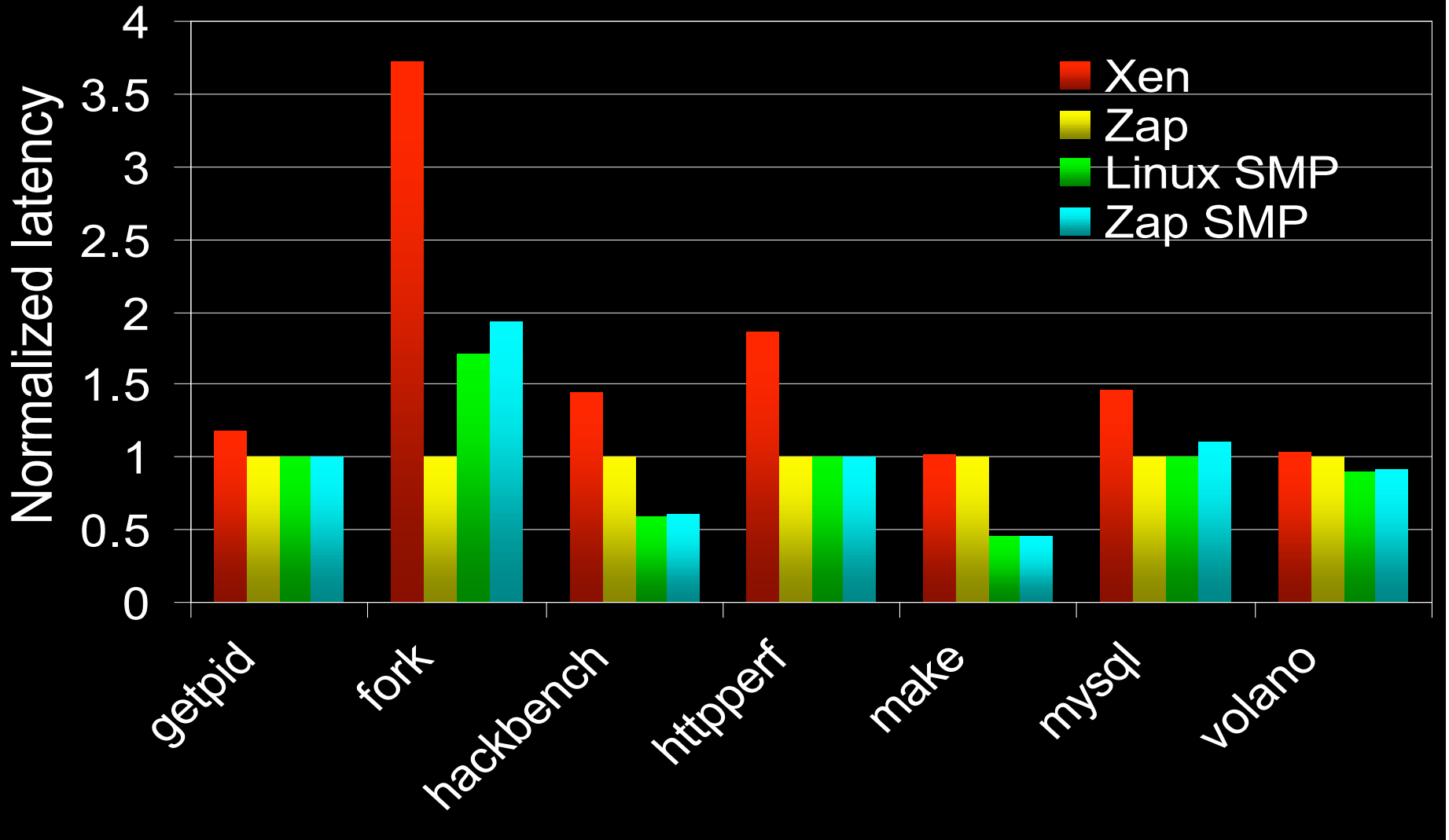
devices

architecture

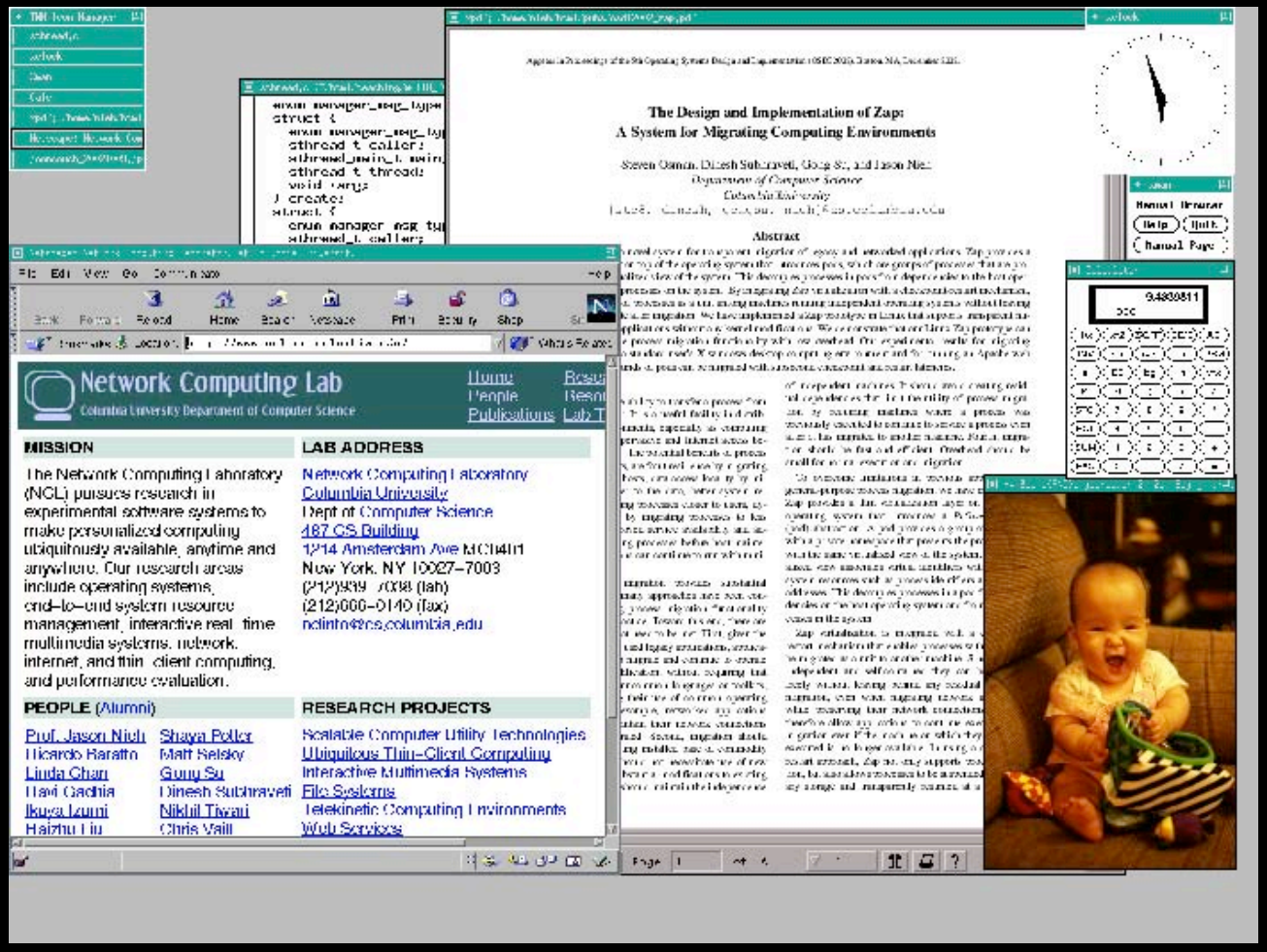
POD virtualization +
checkpoint/restart
kernel module
in Linux

cost?

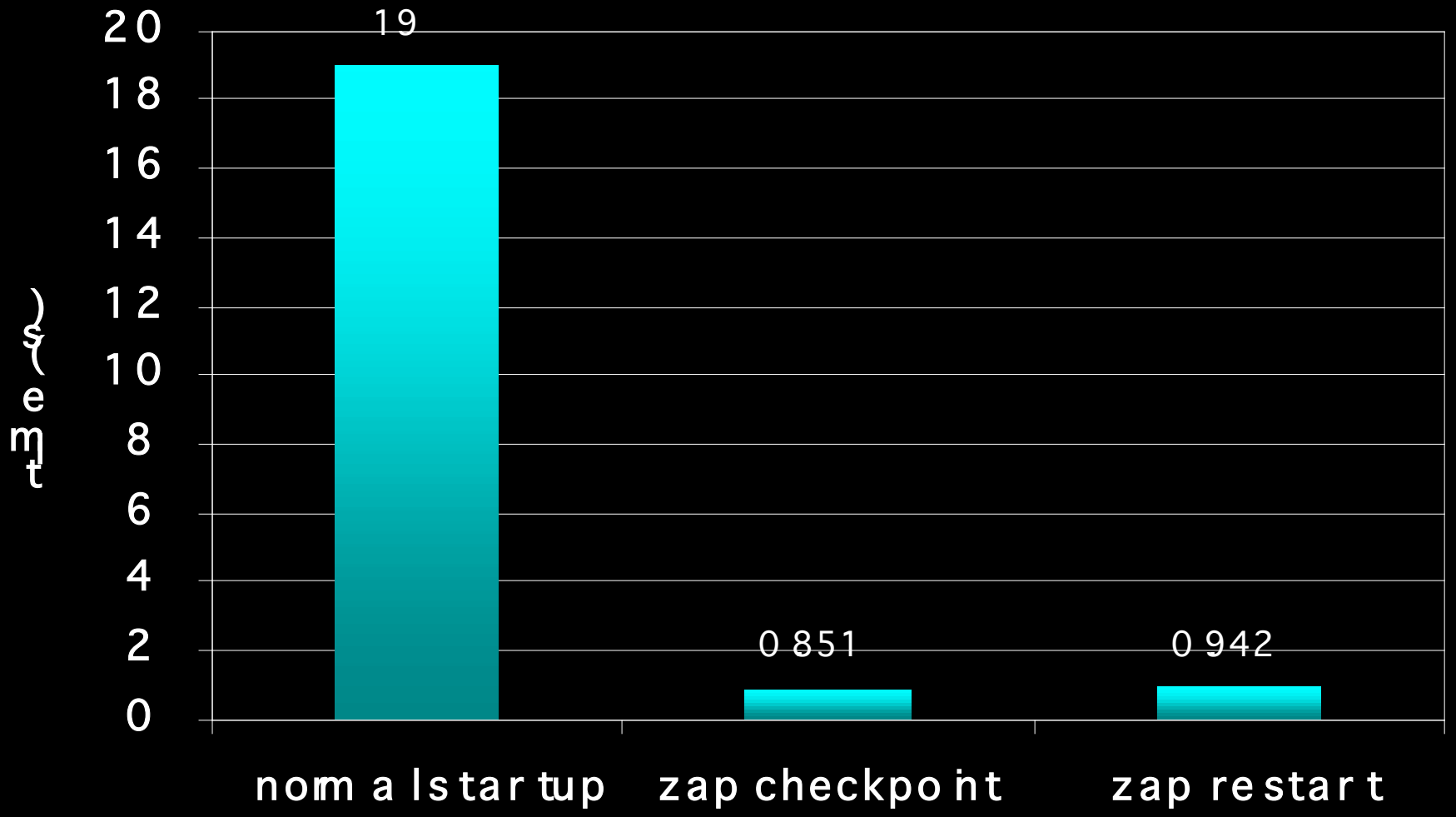
virtualization



remote desktop



checkpoint/restart



zap

transparent checkpoint/migration
of legacy and network applications

POD: consistent, conflict-free,
avoid dependencies

fast and lightweight

conclusions

technology scaling trends are driving thin-client computing

key enabling technologies: remote display and checkpoint/migration

THINC and Zap: display and operating system virtualization mechanisms for thin clients

the future

virtual computing utility
delivered to smart displays

more info

network computing laboratory

http://www.ncl.cs.columbia.edu