thin clients:
back to the future

<JASON NIEH> nieh@cs.columbia.edu
“Computers in the future may weigh no more than 1.5 tons.”

a Popular Mechanics editorial
1949
PCs in use worldwide (2004)

- US: 224 million
- Japan: 69 million
- China: 53 million
- Germany: 46 million
- UK: 36 million
- France: 29 million
- Korea: 26 million
- Italy: 23 million
- Canada: 22 million
- Brazil: 19 million
- Russia: 19 million
- Australia: 14 million
- Mexico: 13 million
- Netherlands: 11 million
- Other: 206 million

PCs in use (in millions)
"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
(Civilian noninstitutional population)

- Percent of households with a computer
- Percent of households with Internet access

<table>
<thead>
<tr>
<th>Year</th>
<th>Computer Use</th>
<th>Internet Access</th>
</tr>
</thead>
<tbody>
<tr>
<td>1984</td>
<td>8.2</td>
<td></td>
</tr>
<tr>
<td>1989</td>
<td>15.0</td>
<td></td>
</tr>
<tr>
<td>1993</td>
<td>22.8</td>
<td></td>
</tr>
<tr>
<td>1997-98</td>
<td>36.6</td>
<td>26.2</td>
</tr>
<tr>
<td>2000</td>
<td>51.0</td>
<td>41.5</td>
</tr>
</tbody>
</table>

Note: Data on Internet access were not collected before 1997.
“There is no reason anyone would want a computer in their home.”

Ken Olson
founder and chairman
Digital Equipment
1977
* 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

display
updates

user
input

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
MOORE'S LAW

transistors


8004 8080 8086

386™ Processor

486™ DX Processor

Pentium® Processor

Pentium® II Processor

Pentium® III Processor

Pentium® 4 Processor

10,000,000

100,000

10,000

100,000

1,000,000

10,000,000

100,000,000

100,000,000
computers are cheap
people are expensive
computers vs people

Dell Dimension 2400 PC desktop, 2.4 GHz CPU, $420

Dell PowerEdge 420 server, 2.4 GHz CPU, $350

move, add, change: $1000 per incident
2004: Percent of Adult Internet Users—Past 30 Days

Used the Following as Primary and Secondary Internet Connection

- A dial-up modem: 30% (First Mention), 39% (Other Mention)
- A DSL (Digital Subscriber Line): 32% (First Mention), 38% (Other Mention)
- High-speed broadband using cable: 17% (First Mention), 21% (Other Mention)
- High-speed broadband using ISDN: 9% (First Mention), 12% (Other Mention)
- High-speed broadband using optical fiber: 3% (First Mention), 7% (Other Mention)
- Using a wireless access/service: 2% (First Mention), 11% (Other Mention)
- Some other connection: 2% (First Mention), 7% (Other Mention)

High-speed access—Total:
- 62% Primary Access
- 68% Total Access

Past 30 Day Internet Users

© Ipsos-Insight 2005
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 of 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 demand 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 Dacon 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...
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.
“the network is the computer”
<table>
<thead>
<tr>
<th>thin clients vs mainframes</th>
</tr>
</thead>
<tbody>
<tr>
<td>rich graphical interfaces</td>
</tr>
<tr>
<td>clusters of inexpensive servers, blades</td>
</tr>
</tbody>
</table>
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
<table>
<thead>
<tr>
<th>thin clients vs web</th>
</tr>
</thead>
<tbody>
<tr>
<td>preserve software investments</td>
</tr>
<tr>
<td>no client applications</td>
</tr>
</tbody>
</table>
key technologies
remote display
display pipeline

- applications
- window system
- display device driver
- framebuffer
Client/server partitioning

Server

Applications

Window system

Display device driver

Client

Framebuffer
window server on client

server

applications

window system

display device driver

client

framebuffer
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

server

applications

window system

display device driver

client

framebuffer
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

high-level requests

raw pixels

applications

window system

device driver

framebuffer
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?
<table>
<thead>
<tr>
<th>name</th>
<th>custom window server</th>
<th>ultra thin</th>
<th>color depth</th>
<th>audio</th>
<th>encryption</th>
<th>OS</th>
</tr>
</thead>
<tbody>
<tr>
<td>local PC</td>
<td>no</td>
<td>N/A</td>
<td>24</td>
<td>yes</td>
<td>N/A</td>
<td>Linux</td>
</tr>
<tr>
<td>ICA</td>
<td>no</td>
<td>yes</td>
<td>24</td>
<td>yes</td>
<td>yes</td>
<td>Windows</td>
</tr>
<tr>
<td>RDP</td>
<td>no</td>
<td>yes</td>
<td>24</td>
<td>yes</td>
<td>yes</td>
<td>Windows</td>
</tr>
<tr>
<td>GoToMyPC</td>
<td>no</td>
<td>yes</td>
<td>8</td>
<td>no</td>
<td>yes</td>
<td>Windows</td>
</tr>
<tr>
<td>X</td>
<td>no</td>
<td>yes</td>
<td>24</td>
<td>yes</td>
<td>no</td>
<td>Linux</td>
</tr>
<tr>
<td>X ssh -C</td>
<td>no</td>
<td>no</td>
<td>24</td>
<td>yes</td>
<td>yes</td>
<td>Linux</td>
</tr>
<tr>
<td>NX</td>
<td>no</td>
<td>no</td>
<td>24</td>
<td>yes</td>
<td>yes</td>
<td>Linux</td>
</tr>
<tr>
<td>VNC</td>
<td>yes</td>
<td>yes</td>
<td>24</td>
<td>no</td>
<td>no</td>
<td>Linux</td>
</tr>
<tr>
<td>Sun Ray</td>
<td>yes</td>
<td>yes</td>
<td>24</td>
<td>yes</td>
<td>yes</td>
<td>Linux</td>
</tr>
<tr>
<td>THINC</td>
<td>no</td>
<td>yes</td>
<td>24</td>
<td>yes</td>
<td>yes</td>
<td>Linux</td>
</tr>
</tbody>
</table>
configurations

desktop LAN

desktop WAN

802.11g PDA
desktop LAN web performance

N/A

PC
ICA
RDP
GoT M yPC
X
X ssh - C
NX
VNC
Sun Ray
TH INC

per web page latency (s)
desktop LAN web performance

PC: 25 29
CA: 147 32
RDP: 203 91
GoToMyPC: N/A
X: 108 4
X ssh -C: 59 33
NX: 205 54
VNC: 228 92
Sun Ray: 126 75
TH INC: 391 8
desktop WAN web performance

PC: 0.77
ICA: 0.79
RDP: 1.05
GoToMyPC: 2.89
X: 1.46
X ssh-C: 1.47
NX: 0.64
VNC: 0.85
SunRay: 1.21
TH INC: 0.64

per web page latency (s)
desktop LAN A/V performance

- PC: 100%
- ICA: 28%
- RDP: 15%
- GoToMyPC: N/A
- X: 100%
- X ssh-C: 76%
- NX: 12%
- VNC: 14%
- SunRay: 3%
- THINC: 100%

audio/video quality
802.11g PDA A/V performance

PC
ICA
RDP
GoTo MyPC
X
X ssh - C
NX
VNC
SunRay
TH INC

aud o/v deo qual ty
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

[Diagram showing: Applications, Libraries, Operating System, Hardware]
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
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

Normalized latency

getpid, fork, hackbench, httpperf, make, mysql, volano
remote desktop
checkpoint/restart

- Normal startup: 19 checkpoints
- Zap checkpoint: 0.851
- Zap restart: 0.942
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