15-410

"Now that we've covered the 1970's..."

Plan 9
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Synchronization

P2 ink advice

- If your paper says “see course staff about ___”, this is our cryptic code
  - It means “You should see a member of the course staff about ____”

Upcoming lectures

- 1.5 weeks of special topics, taught by experts
  - Virtualization, Transactions, Plato, ...
- Week of the 24th-28th - Security
- Final week – various wrap-up
  - “Review session” works best if you come with questions

Synchronization

Survey

- How many have installed *nix on a box?
  - Windows?
- How many have *done an upgrade?*
- How many have a personally owned box with multiple users?
  - Done an upgrade?
- What does “PC” stand for?

Today: Plan 9 from Bell Labs

Overview

What style of computing?

- The death of timesharing
- The "Unix workstation problem"

Design principles

Runtime environment

File servers (TCP file system)

Name spaces

Timesharing

One computer per ...

- City: Multics
- Campus: IBM mainframe
- Department: minicomputer

Benefits

- Sharing, protection easy inside “the community”
  - Easy to add a “user” to access control list (or user group)
- Administration amortized across user base
  - Backups & printers, too...

The *Personal Computing* Revolution

Consequence of the microprocessor

Get *your own* machine!

No more “disk quota”

***You* decide which software is on the box**

- Upgrade whenever *you* want
  - Mainframe sysadmin's schedule is *always* too (fast xor slow)

Great!

The Rallying Cry

One of the Alto's most attractive features is that it does not run faster at night.

- Butler Lampson?

The Personal Computing *Disaster*

You do your own backups

- Probably not!

You do emergency security upgrades

- Day or night!

Sharing files is hard, risky

- machine:/usr/... (until it retires)

Every machine you use has different software

- If you're lucky, packages are just missing
- If you're unlucky, they're there with subtly wrong versions

Hybrid Approach

Centralize "the right" resources

- Backed-up, easily-shared file systems
- Complex (licensed) software packages
- Version management / bug patches

Access those resources from a fast local machine

Which OS on the servers?

- Don't care – black boxes

Which OS on the workstation?

Workstation Operating Systems

Unix?

- Good: It's the system you're used to using
- Bad: Administer it yourself
  - /etc/passwd, /etc/group, anti-relay your sendmail...

Windows

- Your very own copy of VMS!
- Support for organization-wide user directory
- Firm central control over machine
  - “install software” is a privilege
- Access to *services* is tied to *machines*
- Firmly client/server (no distributed execution)

Workstation Operating Systems

Mac OS 9

- Your own ... whatever it was

Mac OS X

- Your own Unix system! (see above)

VM/CMS or MVS!!!

- IBM PC XT/370
- Your own *mainframe*!
  - You and your *whole family* can (must) administer it

The “Network Computer”

Your own display, keyboard, mouse

Log in to a real computer for your real computing

Every keystroke, every mouse click over the net

- Every font glyph...

Also known as

- Thin client, X terminal, Windows Terminal Services

Once “The Next Big Thing”

- (thud)

The Core Issues

Who defines and administers resources?

What travels across the network?

- X terminal: keystrokes, bitmaps
- AFS: files

Are legacy OSs right for this job?

The Plan 9 Approach

“Build a UNIX out of little systems”

- ...not “a system out of little Unixes”

Compatibility of essence with Unix

- Not real portability

Take the good things

- Tree-structured file system
- “Everything is a file” model

Toss the rest (ttys, *signals!*)

Design Principles

"Everything is a file"

- Standard *naming system* for all resources (pathnames)

"Remote access" is the common case

- Standard r*esource access protocol*, 9P
- Used to access any file-like thing, remote or local

Personal namespaces

- Naming *conventions* keep it sane

A practical issue: Open Source

- Unix source not available at "Bell Labs", its birthplace!

System Architecture

Reliable machine-room *file servers*

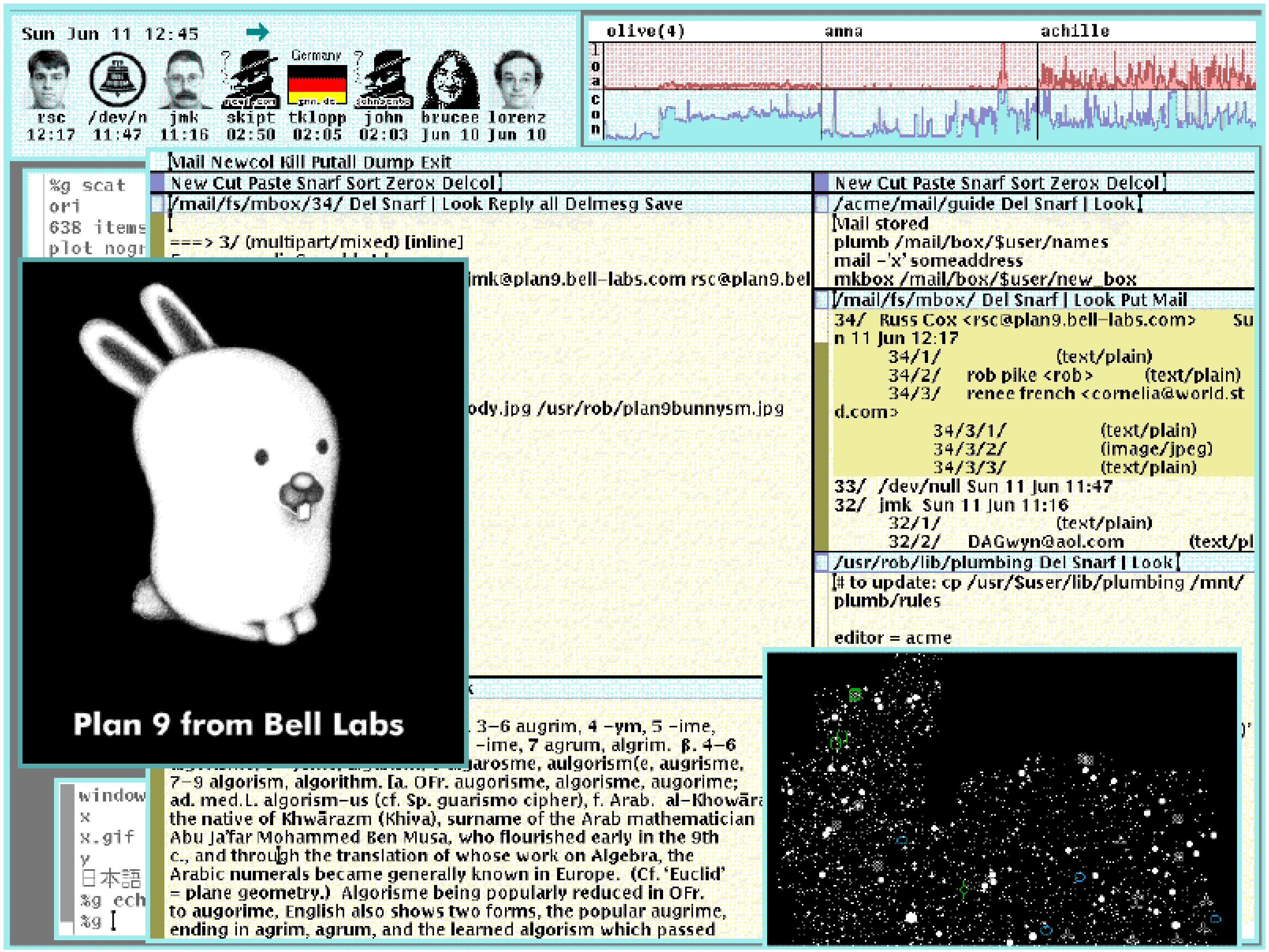
- Plan 9's eternal versioned file system

Shared-memory multiprocessor *cycle servers*

- Located near file servers for fast access

Remote-access workstation *terminals*

- Access your *view* of the environment
- Don't *contain* your environment
- Disk is optional
  - Typically used for faster booting, file cache
- “Root directory” is located on your primary file server



```
Mail Newcol Kill Putall Dump Exit
New Cut Paste Snarf Sort Zerox Delcol
/mail/fs/mbox/34/ Del Snarf | Look Reply all Delmesg Save

===> 3/ (multipart/mixed) [inline]
jmk@plan9.bell-labs.com rsc@plan9.bel
ody.jpg /usr/rob/plan9bunnysm.jpg
```

```
. 3–6 augrim, 4 –ym, 5 –ime,
–ime, 7 agrum, algrim. β. 4–6
agarosme, aulgorism(e, augrisme,
7–9 algorism, algorithm. [a. OFr. augorisme, algorisme, augorime;
ad. med.L. algorism–us (cf. Sp. guarismo cipher), f. Arab. al–Khowāra
the native of Khwārazm (Khiva), surname of the Arab mathematician
Abu Ja'far Mohammed Ben Musa, who flourished early in the 9th
c., and through the translation of whose work on Algebra, the
Arabic numerals became generally known in Europe. (Cf. 'Euclid'
= plane geometry.) Algorisme being popularly reduced in OFr.
to augorime, English also shows two forms, the popular augrime,
ending in agrim, agrum, and the learned algorism which passed
```

```
New Cut Paste Snarf Sort Zerox Delcol
/acme/mail/guide Del Snarf | Look
Mail stored
plumb /mail/box/$user/names
mail –'x' someaddress
mkbox /mail/box/$user/new_box
/mail/fs/mbox/ Del Snarf | Look Put Mail
34/  Russ Cox <rsc@plan9.bell–labs.com>      Su
n 11 Jun 12:17
      34/1/               (text/plain)
      34/2/    rob pike <rob>       (text/plain)
      34/3/    renee french <cornelia@world.st
d.com>
         34/3/1/              (text/plain)
         34/3/2/              (image/jpeg)
         34/3/3/              (text/plain)
33/  /dev/null Sun 11 Jun 11:47
32/  jmk  Sun 11 Jun 11:16
      32/1/               (text/plain)
      32/2/    DAGwyn@aol.com         (text/pl
/usr/rob/lib/plumbing Del Snarf | Look
# to update: cp /usr/$user/lib/plumbing /mnt/
plumb/rules

editor = acme
```

```
%g scat
ori
638 items
plot nogr
```

```
window
x
x.gif
y
日本語
%g ech
%g
```

Custom Namespaces

/bin/date means *your architecture*'s binary

/dev/cons means *your* terminal

- Per-*window* devices (below)

/mail/fs/mbox/25 is the 25th message in your box

No “links” - “hard” or “soft”

- A link is something in the file system which causes everybody to buy into a naming illusion
  - Some illusions cause security holes, as we've seen
- In Plan 9, namespaces are *consensual* illusions

The /bin File System

Look, Ma, no $PATH!

```
% bind /386/bin /bin
% bind -a /rc/bin /bin
% bind -a /usr/davide/386/bin /bin
```

/bin is a *union* directory

- **Each backing directory searched in order**

/dev/tty vs. /dev/cons

```
% (process_foo <foo >bar ) >&errs
```

- csh-speak for
  - Run “process_foo”
  - Standard input is “foo”
  - Standard output sent to “bar”
  - Standard error sent to “errs”

“process_foo” is pretty well connected to *files*

- What if it wants to talk *to the user?*

/dev/tty vs. /dev/cons

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Unix solution – magic device “/dev/tty”

- Rummages through your process, guesses your terminal
  - See O_NOCTTY flag to open(2), see vhangup(2)–or don't...
- Opens /dev/ttyXX for you, returns that

/dev/tty vs. /dev/cons

```
% (process_foo <foo >bar ) >&errs
```

What if process_foo wants to talk *to the user?*

Plan 9 – correct *namespace* contains /dev/cons

- The right device is *mounted* as /dev/cons
- By whoever runs you
  - window manager, login, remote login
- Unix question: what is the name of the terminal I'm running on? ttyp7? ttyq9?
- Plan 9 answer: whoever connected you to that terminal arranged for it to have the conventional name - /dev/cons

/dev/tty vs. /dev/cons

Unix remote login

- /dev/tty delegates to /dev/ttyp1
  - “pseudo-tty” - careful emulation of a serial line
- master (/dev/ptyp1) is managed by sshd
- ASCII characters flow across the network
- Your ssh client is running on /dev/ttyq3
  - Which is connected to a screen window by “xterm”
- What happens when you resize your xterm??

Plan 9 remote login

- Shell's /dev/cons is a *remote mount* of a window
- Same as if the window were local (albeit slower)

Per-Window Devices

X: a complex monolithic server somewhere

- House of a thousand mysteries
- *Not* on the 15-410 reading list: ICCCM
  - "Inter-client communication conventions manual"

Plan 9: Per-*window* devices

- I/O - /dev/mouse, /dev/cursor, /dev/cons
- Contents - /dev/text, /dev/window
- /dev/label - window title
- /dev/wdir – working directory

```
% echo top > /dev/wctl
```

  - Requests window manager to bring your window to top

Per-Window Devices

Screen shot

```
% cp /dev/screen /tmp/screen-image
```

Window shot

```
% cp /dev/window /tmp/window-image
```

The Serial-Port File System

Look, Ma, no ioctl()!

```
% bind -a '#t' /dev
% echo b9600 > /dev/eia1ctl
% echo “foo” > /dev/eia1
```

The TCP File System

Look, Ma, no finger command!

```
#!/bin/rc
# hold clone, ctl open during connection
{ conn=`{read} cd /net/tcp/$conn
 { echo 'connect 128.2.194.80!79' > ctl ;
   echo davide > data; cat data } < ctl
} < /net/tcp/clone
```

Look, Ma, no NAT proxy setup!

```
  % import gateway.srv /net/tcp
```

The CD-Burner File System

Burn audio tracks to CD

```
% cdfs -d /dev/sdD0
% cp *.cda /mnt/cd/wa/
% rm /mnt/cd/wa
% echo eject > /mnt/cd/ctl
```

The tar-ball File System

Rummage through a tar file

```
% fs/tarfs -m /n/tarball foo.tar
% cat /n/tarball/README
```

The /tmp Problem

Unix /tmp: security hole generator

Programs write /tmp/program.3802398

- Or /tmp/program.$USER.3432432

No name collision “in practice”

- Unless *an adversary* is doing the practicing

```
% ln -s /tmp/program.3802398 /.cshrc
```

- Now a setuid-root program will put your commands into root's .cshrc...

Fixing /tmp

No inter-user security problem if *only one user!*

Plan 9 /tmp is per-user

- User chooses what backs the /tmp name
  - Temporary “RAM disk” file system?
  - /usr/$user/tmp

Matches (sloppy) programmer mental model

Plan 9 3-Level File Store

Exports one tree spanning many disks

- Users bind parts of the tree into namespaces

Original implementation – 3-level store

- RAM caches disks, disks cache WORM jukebox

Plug-compatible modern implementation

- Hash-capability log-structured disk store

Daily snapshots, available forever

- /n/dump/1995/0315 is 1995-03-15 snapshot
- Time travel without “restoring from tape”
- Public files are *eternally* public – be careful!

Plan 9 Process Model

New-process model

- fork()/mount()/exec()

System calls block

Task/thread continuum via rfork()

- Resources are shared/copied/blank
  - Namespace, environment strings
  - File descriptor table, memory segments, notes
  - Rendezvous space
- rfork() w/o “new process” bit edits current process

Process Synchronization

rendezvous(tag, value)

- Sleeps until a 2nd process presents matching tag
- Two processes swap values
- "Tag space" sharing via rfork() like other resources

Shared-memory spin-locks

Summary

Files, files, files

- "Plumber" paper
  - Programmable file server
  - Parses strings, extracts filenames
  - Sends filenames to programs
  - File, file, blah, blah, ho hum?
- Isn't it cleaner than
  - Sockets, ICCCM, RPC program numbers, CORBA?

Not just another reimplementation of 1970

- Every compile is a cross-compile
- Every debug is a remote cross-platform debug
- Unicode everywhere
- ...

More Information

“Gold Server” multi-computer environment approach

- How to build a system out of a bunch of Unixes
- Similar approach to Andrew
- Difficult
- http://www.infrastructures.org/papers/bootstrap/

Plan 9

- http://www.cs.bell-labs.com/plan9/

Disclaimer

A distributed system is a system in which I can't do my work because some computer has failed that I've never even heard of.

- **Leslie Lamport**