# 15-410

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

## Plan 9
## Nov. 25, 2019

**Dave Eckhardt**

# Overview

**"The land that time forgot"**

**What style of computing?**

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

**Design principles**

**Name spaces**

**File servers**

- The TCP file system...

**Runtime environment**

# The Land That Time Forgot

**The "multi-core revolution" already happened once**

- 1982: VAX-11/782 (dual-core)
- 1984: Sequent Balance 8000 (12 x NS32032)
- 1985: Encore MultiMax (20 x NS32032)
- 1990: Omron Luna88k workstation (4 x Motorola 88100)
- 1991: KSR1 (1088 x KSR1)
- 1991: "MCS" paper on multi-processor locking algorithms
- 1995: BeBox workstation (2 x PowerPC 603)

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## Wow!

- Why was 1995-2004 ruled by single-core machines?
- What operating systems did those multi-core machines run?

# The Land That Time Forgot

## Why was 1995-2004 ruled by single-core machines?

- In 1995 Intel + Microsoft made it feasible to buy a fast processor that fit on one chip, a fast I/O bus, multiple megabytes of RAM, and an OS with memory protection.
- *Everybody* could afford a "workstation", so everybody bought one.
- Massive economies of scale existed in the single-processor "Wintel" universe.
- Investment in expensive multi-core technologies sank – huge "lateness risk"

# The Land That Time Forgot

**What operating systems did those multi-core machines run?**

- Various company ports of BSD Unix, System V Unix
- Research operating systems
  - Sprite (Berkeley)
  - Amoeba (Vrije Universiteit Amsterdam)
  - V (Stanford)
  - ChorusOS (INRIA)
  - LOCUS (UCLA)
  - Mach (CMU)
  - Plan 9 (Bell Labs)
  - BeOS (Be Inc.)

# The Land That Time Forgot

**What happened to all of those operating systems?**

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# The Land That Time Forgot

**What happened to Mach?**

**What the heck was/is “Plan 9”?**

# The Land That Time Forgot

## What happened to Mach?

- Basis of NextStep, then XNU (OS X and iOS)

## What the heck was/is “Plan 9”?

- Funny you should ask!

## Outline

- The death of timesharing
- The “Unix workstation problem”
- Design principles
- Name spaces
- File servers
- Runtime environment

# Evolution (?) of 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
  - Or different machines have different fonts – whee!

# Hybrid Approach

## A form of distributed computing

- 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 cross the net
  - Every font glyph...
- Also known as
  - Thin client, X terminal, Windows Terminal Services
- Once “The Next Big Thing”
  - (thud)

# The Core Issues

1. **Who defines and administers resources?**
   - One administrator per ...?
     - Department?
     - Laptop?
2. **What travels across the network?**
   - X terminal: keystrokes, bitmaps... lots of little things
   - AFS: files... as long as your sharing pattern matches

**Are legacy OS's 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/redesign the rest (ttys, *signals!*)**

# Design Principles

**"Everything is a file"**

- Standard *naming system* for all resources: pathnames

**"Remote access" is the common case**

- Standard *resource 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***

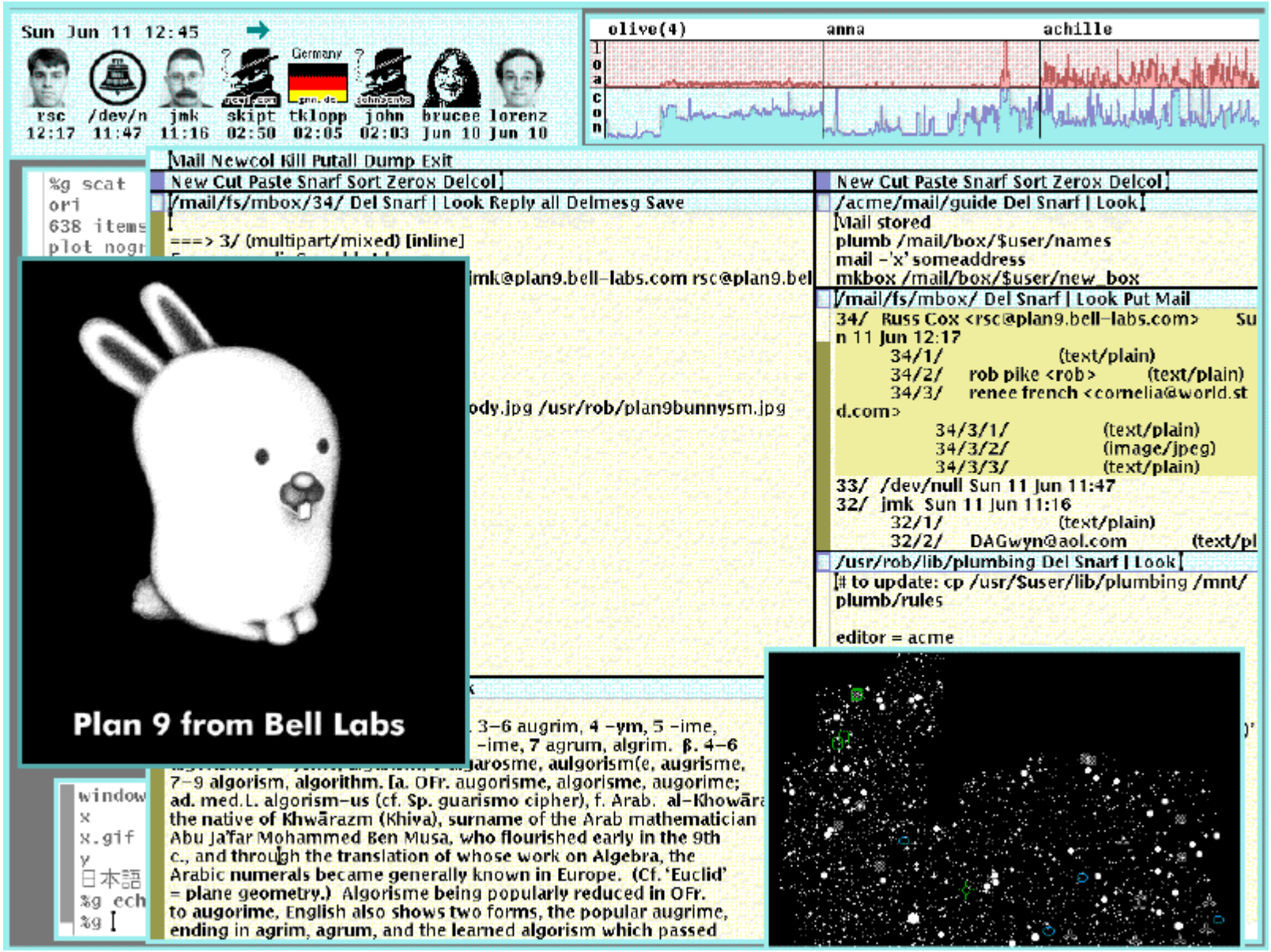
- Plan 9's eternal versioned file system

**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


Sun Jun 11 12:45
rsc 12:17
/dev/n 11:47
jmk 11:16
skipt 02:50
tklopp 02:05
john 02:03
brucee Jun 10
lorenz Jun 10
Germany
olive(4)
anna
achille
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]
/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>
34/1/ (text/plain)
34/2/ rob pike <rob> (text/plain)
34/3/ renee french <cornelia@world.std.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
/usr/rob/lib/plumbing Del Snarf | Look
# to update: cp /usr/$user/lib/plumbing /mnt/plumb/rules
editor = acme
Plan 9 from Bell Labs

# Outline

**Namespaces**

**Unusual file systems**

**A slightly irregular file system**

**Run-time environment**

# 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
  - List of mount points for partial file systems
  - Stored in process control blocks, not in the file system

# Namespace Sample (trimmed)

```
cpu% ns
bind  '#c' /dev
bind  '#d' /fd
bind -c '#e' /env
bind  '#p' /proc
bind -c '#s' /srv
bind -a '#S' /dev
mount -a '#s/slashn' /n
mount -a '#s/factotum' /mnt
bind  /386/bin /bin
bind -a /rc/bin /bin
bind -a '#l' /net
bind -a '#I' /net
mount -a '#s/cs' /net
mount -a '#s/dns' /net
mount -c '#D/ssl/0/data' /mnt/term
bind -b /usr/davide/bin/rc /bin
bind -b /usr/davide/bin/386 /bin
bind -c /usr/davide/tmp /tmp
bind  /mnt/term/dev/cons /dev/cons
bind  /mnt/term/dev/consctl /dev/consctl
bind -a /mnt/term/dev /dev
mount  '#s/rio.davide.317464' /mnt/wsys 1
mount -b '#s/rio.davide.317464' /dev
cd /usr/davide
cpu%
```

# 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 by open(), exec(), ...

# /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

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

- csh-speak for
  - Run "process_foo"
  - Standard input is "foo"
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**"process_foo" is pretty well connected to *files***

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

**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 – your *namespace* contains /dev/cons**

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

# /dev/tty vs. /dev/cons

## Unix remote login

- csh talks to /dev/tty (delegated to /dev/ttyp1)
  - "pseudo-tty" - careful emulation of a serial line
- Pseudo-tty master (/dev/ptyp1) is managed by sshd
- ASCII characters flow across the network, plus signals!
- 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 file mount* of a window
- Same as if the window were local (albeit slower)
- One protocol: read()/write(), running over 9P

# *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
- Window title - /dev/label (a 1-line text file)
- Working directory - /dev/wdir

```
% 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 CD-Burner File System

**Burn audio tracks to CD**

```
% cdfs -d /dev/sdD0
```

- Uses /dev/sdD0/raw to send SCSI commands to hardware
- Mounts itself as /mnt/cd in your namespace

```
% cp *.cda /mnt/cd/wa/
```

- Write CD-Audio tracks to the “write audio” directory

```
% rm /mnt/cd/wa
```

- Remove “write audio” directory to indicate “done writing”
- cdfs will “finalize” the CD

```
% 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 TCP File System

**Look, Ma, no finger command!**

```
#!/bin/rc
# hold clone & ctl open during connection
{ conn=`{read} cd /net/tcp/$conn
 { echo 'connect 128.2.42.9!79' > ctl ;
   echo de0u > data; cat data } < ctl
} < /net/tcp/clone
```

**Look, Ma, no NAT proxy setup!**

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

# 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 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()/bind(), 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 locks**

- Spin-lock, queue-lock

# Summary

## Files, files, files

- "Plumber" paper
  - Programmable file server
  - Parses strings, extracts filenames
  - Sends filenames to programs
  - File, file, blah, blah, ho hum?
- Why be boring and simple? Why not be exciting?!
  - Sockets, ICCCM, RPC program numbers, CORBA

# Summary

## What's it *good* for?

- IBM Blue Gene supercomputer
- Raspberry Pi super-*cheap*-computer
- Being able to read your entire kernel in finite time
- [Nice student-sized 15-412 projects!]

## 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/bootstrap.html

## Modern tools you should know about

- Puppet – http://docs.puppetlabs.com
- Chef – http://docs.opscode.com
- Docker – http://www.docker.com

## Plan 9

- http://www.cs.bell-labs.com/plan9/ (sometimes)
- http://9legacy.org http://9atom.org http://9front.org

# 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**