Themes in Operating Systems Research

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Unix Origins (1969-)

- Bell Labs has a long history in early operating systems, for example BE-SYS for IBM machines, Multics
- Ken Thompson wanted to write a computer operating system:
  - Explore structures for building OS
  - Build something for our group to use
- Fundamental idea: a good way to represent data (disk files)
- First steps:
  - find representation for data
  - define access methods to data
- Earliest Unix simply tried to build some superstructure to test the ideas

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Main early ideas (1969-72)

- Much inherited (e.g. from Multics project)
- Files contain just a sequence of bytes
  - interpretation is up to applications
  - optimization is up to operating system
  - preference is for files with readable text
- Files are named in a hierarchical, tree-like name space, for example
  `/usr/dmr/china/chinaslides`

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File system operations

- Basic operations are simple:

  handle = open(filename, read-or-write-desire)
  handle = create(filename, protection-mode)

  read(handle, buffer, nbytes)
  write(handle, buffer, nbytes)

  close(handle)

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Hierarchical names

```
/
 -- source
    -- shell
        -- sh1.c
        -- ...
    -- ...
--  usr
    -- ken
    -- dmr
        -- china
            -- chinaslides
    -- ...
--  binary
    -- sh
    -- ...
-- ...
```


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Names for other things

- Hierarchical naming is standard now
- Unix introduced a consistent abstraction: names for I/O devices as part of the same hierarchy, for example

  `/dev/tty23`

  (name of terminal 23)

  `/dev/disk/disk03`

  (name of a whole disk)

  `/dev/mem`

  (name for main memory)

- These really exist in the file system, and the same protections and ownership properties are applied to them as to "ordinary" files
- To the extent possible, they look like the same byte streams as plain disk disk files.

  Some (like terminals) have some special operations that apply, to change modes: "I/O controls"

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Remoting the file system

- By 1980s, Sun (with NFS), AT&T Computer Systems (RFS) and Bell Labs Research (NetA) were building "remote file systems"
  - Using RPC (remote procedure call) mechanisms, attach file system hierarchies on other machines to a local machine
- Important generalization: approach to a distributed system transparent to applications
- Some problems:
  - How usable are remote devices?
    (some technical problems with protocols)
  - How usable are remote resources?
    (interworking across machine architectures, e.g. differences in byte ordering)

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Unix results

- results have been influential:
  - academic, commercial, research use in 1970s building on growth of minicomputer industry
  - widespread use in 1980s following growth of workstation industry
  - current industry and private interest centers on "open software" movement, enabled by open Unix standards
  - other systems have been much influenced by these standards

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Another step: Plan 9 (1990-)

- Original idea: define a remote protocol (called 9P) to talk to a remote file system
- Unix began with a structural idea:
  How to represent a local file system?
- Plan 9 began with this structural idea:
  Definition of protocol to communicate with resources

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Plan 9 Idea 1:

- Put all system resources into file system names:

```
/dev/console   (terminal data)
/dev/consctl   (terminal control)
/dev/mouse   (current mouse location)
/proc   (information about processes)
  mem
     stack
     status
     control   (start/stop processes)
  …
/net
    tcp
        clone   (create connection)
        tcp05
            data   (send/receive data)
            control
            status
    dns (domain name server)
    udp
    ...
```


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Plan 9 Idea 2

- Naming scheme for files can be changed by user
- Can locally bind remote files and resources using appropriate server
- Name space of resources is adaptable for each user even on shared machines

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Example: Network access

- Access to network devices is through files
- Pieces of another machine's file space can be imported
- Thus, programs on one machine can 'borrow' network interfaces from servers
- For example, on a machine on Bell Labs internal network:

% telnet stanford.edu

```
telnet: Cannot translate address stanford.edu
```

% import internetgate.bell-labs.com /net

(this binds the Internet gateway's network directory into my own; now my '/net' uses the one connected to the outside)

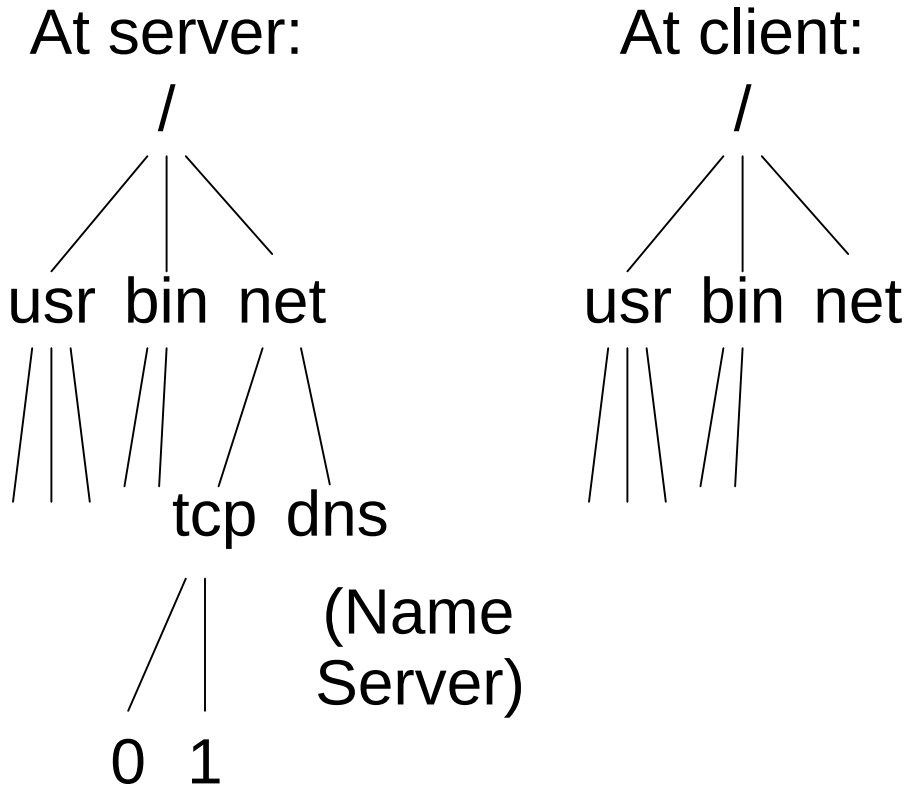
% telnet stanford.edu

```
connected to tcp!stanford.edu!telnet on /net/tcp/15
ULTRIX V4.2A (Rev. 47) (Argus.Stanford.EDU)
login:
```


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Network example (before)

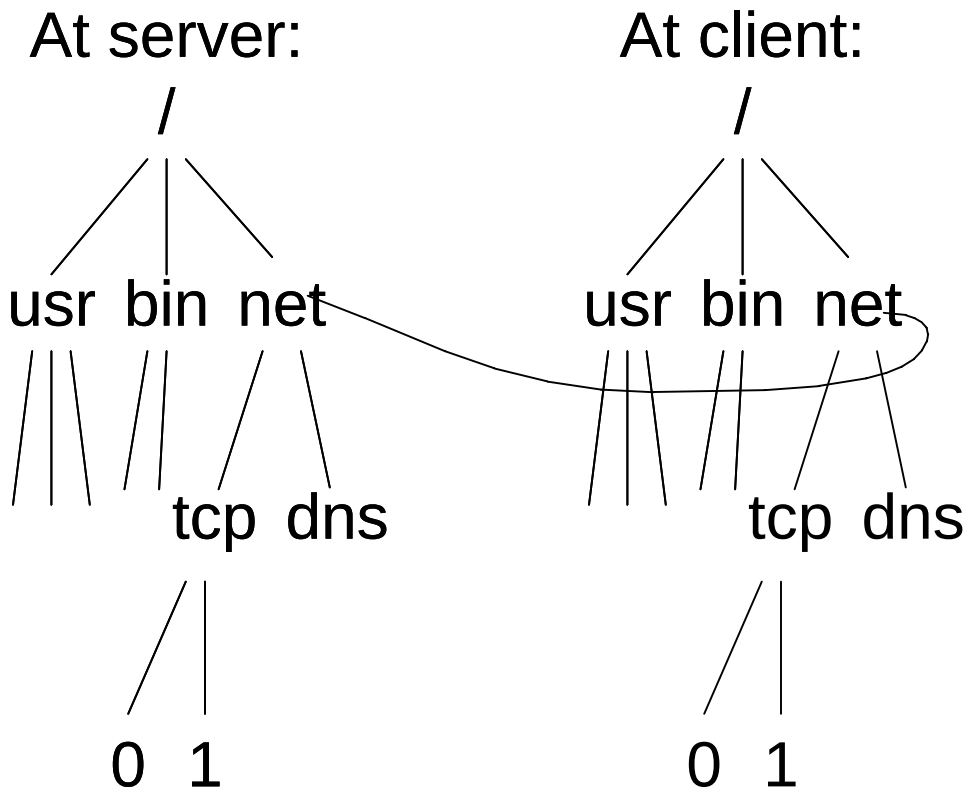


DNS: Domain Name Server /net/dns

TCP connection: /net/tcp/0/...



Network example (after import)



Plan 9 Example 2

- Exotic file systems can be created building on standard, old protocols like "File Transfer Protocol" – FTP
- Works by changing name space so `/n/ftp` accesses a server that turns reads and writes into FTP requests:

% ftpfs ftp.microsoft.com /n/ftp

```
220 ftp Windows NT FTP Server (Version 3.5).
331 Anonymous access allowed.
  Welcome to ftp.microsoft.com!
230 Anonymous user logged in for guest access.
215 Windows_NT version 3.51
```

% ls –l /n/ftp

```
dr-xr-xr-x owner       0 Apr 18 14:10 KBHelp
-r-xr-xr-x owner   54310 Apr 19 03:52 LS-LR.ZIP
-r-xr-xr-x owner   28160 Nov 28 02:19 MSNBRO.DOC
```


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Plan 9 Idea 3

- Try to make data machine-independent
  - use text representation where possible, for example text, instead of binary messages for control of devices
  - use files to connect programs, for example

    write `"connect tcp!135.104.3.11"`

    to start TCP connection instead of transmitting a binary structure
  - Text works across remote file systems
  - encourage a more universal character set readily represented in bytes, like Unicode in UTF-8 encoding (helpful for 中国人?)



Main themes here

- Unix was strong in terms of portability of code
- More recent work has tried to advance portability of applications and access to data

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Inferno

- Inferno is a system that combines the system-structure ideas from Unix and Plan 9 with a new one:
- A "virtual operating system" that can run either stand-alone on a small device like a hand-held or TV set-top, or as an application under conventional operating systems like Windows or Unix
- Idea continued to push on application and data portability: same, seamless system on small device and central server
- By chance and circumstance, similar ideas were re-emerging with Java language and Jini at about the same time
- Business venture was started with this: recently it was spun off:

  `www.vitanuova.com`



Results in industry

- A vigorous Unix industry in workstations, PCs, and mainframe + supercomputers
- Assimilation of many ideas even into competing products
- Most recently, a rapidly growing "open software" movement with Linux and BSD systems based on Unix specifications for OS and applications

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Lucent Results – Pathstar Access Server

- Some current Lucent products are based directly on this work
  - Pathstar Access Server
    An Internet Protocol router designed to be useful for telephony applications as an end-office (Class 5) telephone switch: it handles
    - ordinary voice telephone with usual features
    - data applications (IP using standard protocols)
    - aggregation of data and voice using DSL
    - a wide variety of end-connection mechanisms (plain telephone, fiber links etc.)
  - Uses Inferno for its operating system

    `http://www.lucent.com/ins/products/pas/index.html`



Lucent Managed Firewall

- Lucent Managed Firewall
  An Internet-to-Intranet safety interface, with packet and content filtering
  - Uses Inferno as the operating system for its central element: "the brick"

`http://www.lucent.com/ins/products/managedfirewall.html`



Viaduct mini-brick

- Viaduct
  - Very small box (15 cm long) acts as a firewall for homes and small offices using direct Internet connections via DSL or cable modems
  - Does encryption and compression of data, and provides secure tunneling between the home and a corporate network
  - no administration needed–just plug it in
- Uses Plan 9 as its operating system

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Summary

- This line of research has been very fruitful
  - Unix and its offspring have been successful and influential (especially lively today in Linux and similar systems)
  - Adoption of ideas pioneered at Bell Labs is pervasive: for example regular expressions for searching– specifying wildcard file names, text searches in an editor, WWW searches
  - Challenge is to find research topics in communications and computers that will be as influential for Lucent and the industry in the future as what has already been done
  - This is equally so both for Bell Labs Research in China and for Bell Labs in the US

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