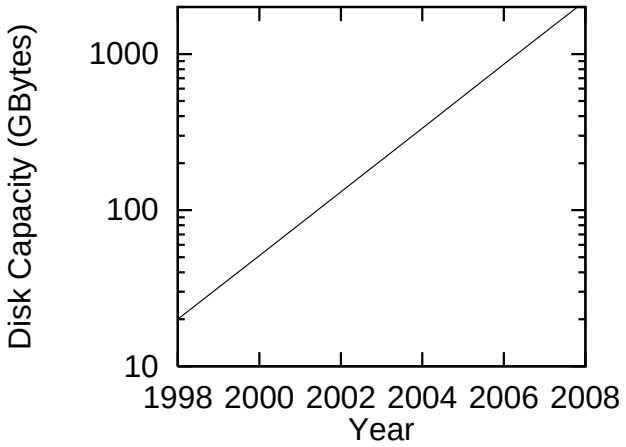
The Personal Terabyte

Ann L. Chervenak
College of Computing, Georgia Tech

Motivation

Magnetic disks: massive, inexpensive storage



- **Capacity increases 60% per year**
- 5 to 8 years: Terabyte on a disk
- 10 years: $300 buys a terabyte

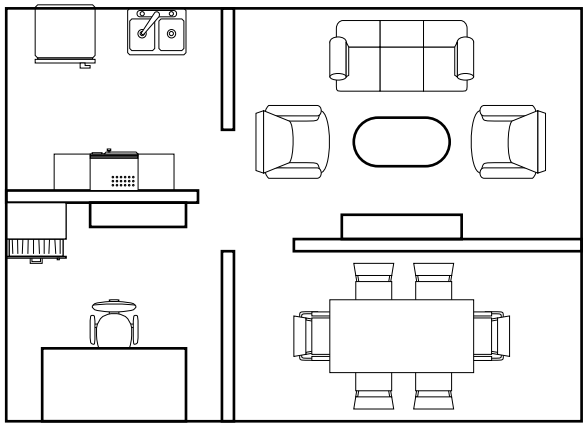
A "Personal Terabyte" for the home user

How to manage and exploit the Personal Terabyte?

Outline

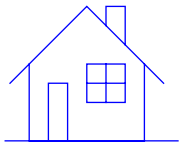
- **The Home Environment and Workload**
- **Overview of Research Issues**
  - Prefetching from the Personal Terabyte disk
  - Prefetching from the World Wide Web
  - Backup and Reliability
  - Disk System Architecture and File System Issues
- **Summary**

The Home Environment



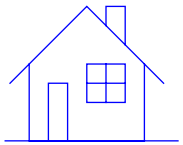
- **Multiple Network Connections to Outside World**
  - High-bandwidth, low-cost broadcast
    (cable, satellite) Gbits/sec
  - Lower-bandwidth, higher-cost point-to-point
    (wired and wireless) Tens of Mbits/sec

The Home Environment



- **Network within the home**
  - Connect appliances, security system, etc.
  - Ethernet, Firewire, CEBus
- **Compute engines, displays**
- **The Personal Terabyte**
  - Single disk or disk array?
  - Central server or distributed?
  - Traditional or new disk architecture?

The Home Workload



Prefetch, cache and pre-process WWW data

Archive of personal and family data

- Home movies, photographs

Storage, playback of entertainment video

Information databases

Games, virtual environments

Work: Simulations, large data sets

Security system: video monitoring of children, pets

Word processors, spreadsheets, etc.

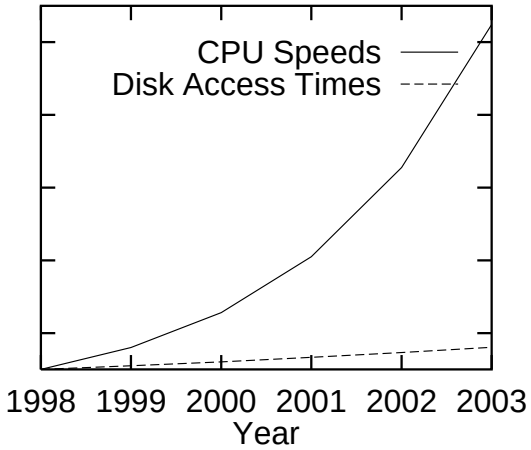
Outline

- **The Home Environment and Workload**
- **Overview of Research Issues**
  - Prefetching from the Personal Terabyte disk
  - Prefetching from the World Wide Web
  - Backup and Reliability
  - Disk System Architecture and File System Issues
- **Summary**

Prefetching from the Personal Terabyte Disk

Increasing gap between CPU and disk speeds

CPU: 60%/year Disk: 10%/year



Page Faults Take Millions of Clock Cycles:
Prefetch disk pages into memory

Techniques: Disk readahead or
application or Operating system prediction

Prefetching From Disk to Main Memory

Two main prefetching approaches:

1. **Applications provide *deterministic* "hints" of what blocks they will access**
   - Decide *whether to prefetch* a block based on **cost-benefit analysis**
   - Hugo Patterson (CMU)

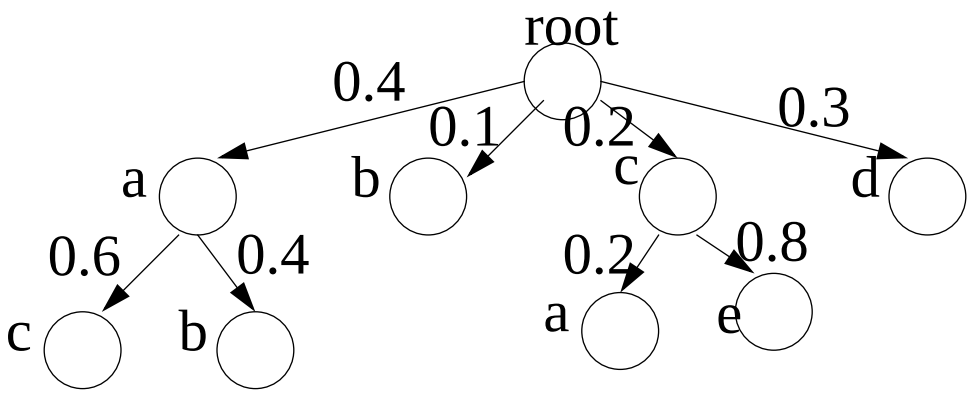
2. **Predict future accesses based on past accesses**
   - ***Probabilistic* hints** or predictions
   - Probability trees (Duke, Kentucky), Markov models (Illinois)

Our Approach: a Hybrid Scheme

***What to prefetch*: predict based on past**
***Whether to prefetch*: use cost/benefit analysis**

Deciding What to Prefetch

- Algorithm from Duke University:
  Probability tree updated on every access



Prefetch candidates:
high probability of being accessed

Deciding Whether to Prefetch: Cost-Benefit Analysis

Adapted from Hugo Patterson's Informed Prefetching

Must calculate:

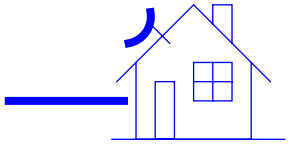
- **Benefit of allocating a cache buffer** to prefetch an additional block
- **Cost to reclaim a buffer** from the ***demand cache*** or ***prefetch cache*** to hold the prefetched block

Prefetch block only when *benefit exceeds cost*

Prefetching and Caching World Wide Web Data

Prefetch/cache a subset of WWW

- Avoid network and server delays



Cache general interest data from broadcasts

- **Filter data** based on user interests
- Even Personal Terabyte can’t store everything

Prefetch data for specific interests over Internet

- Generate network traffic: responsible prefetching

Prefetching from World Wide Web

WebSnatcher

- **Customized prefetching** of WWW data
- Periodically prefetch according to user profile
- Store results on local disk
- **Avoid delays** from network and server loads

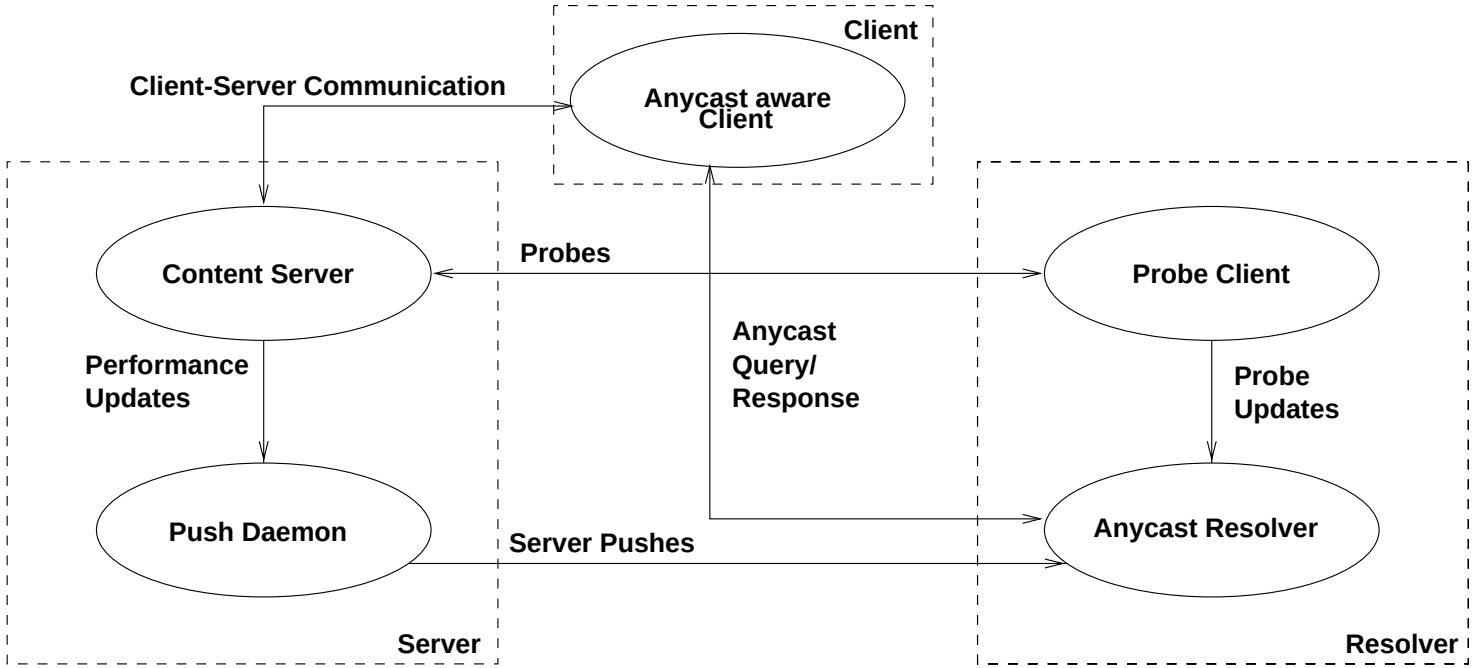
Profile includes:

- List of servers that are **“functionally equivalent”**
- Used for **anycasting**

Anycasting: Using Experience to Guide Server Selection

With Prof. Ellen Zegura

"Anycasting": specify a service, can go to any one of a collection of servers



Importance: Responsible prefetching, Performance

Resolver Selection Algorithms

Average: Choose server with best mean performance

Moving Weighted Average: Choose server with smallest moving weighted average (Weigh recent history more heavily)

- $D_{0,j} = X_{0,j}$
- $D_{i,j} = \alpha X_{i,j} + (1-\alpha)D_{i-1,j}$

Minimum: Visit each server periodically, choose server with minimum response times

Hop Count: Choose server with smallest hop count from client machine to server (use traceroute)

Round Robin: Select servers in round robin fashion

Evaluating Resolver Algorithms

Experiments with four anycast groups:
News stories, Seattle weather forecast,
“Today in history”, Leo Horoscope

Average and **moving weighted avg.** close to optimal

Hop count, round robin perform poorly
Don’t use past experience

Importance:

- Automatically generate network traffic:
  must be responsible
  - Choose server with quick response to
    reduce network and server load
- Improve performance for interactive applications

Protecting the Reliability of Personal Terabyte Data

Disk Array Techniques

- Protect against individual component failures
- Will consumers buy extra disks for reliability?

Still need recovery from disasters,
recovery of accidentally-deleted files

Traditional full backups will take longer

- Capacity increases 60% per year
- Transfer rate 40% per year

Desirable Backup Features for the Personal Terabyte

Incremental-only backup schemes

- Write file when it is created
- Then only write incremental changes

Snapshots and **copy-on-write**

- On-line backup, save old versions of files

Selective backup, compression

Automated network backup off-site

- Few backup home data

Measuring College of Computing backup system, evaluating incremental-only algorithm

Personal Terabyte Storage Architecture

Centralized or distributed server

- Information furnace
- One disk or an array

Network-Attached Disks

- Data need not pass through host

Active or Intelligent Disks

- Partition applications, run part on disk's CPU
- **Home applications:**
  - **Optimize** disk layout for **backup**
  - Background **reorganization of data**
  - **Processing, delivering** multimedia data

File System Organization

Must support:

- **Large files**
- **Large numbers of files**
- **Efficient storage and retrieval**

Block sizes

- Fixed blocks, multiple block sizes or extents

Metadata

- Inodes
- Limited levels of indirection (Frangipani)
- B-Trees (XFS)

Summary: Managing and Exploiting the Personal Terabyte

- **Prefetching from the Personal Terabyte disk**
  - Cost-benefit analysis, predictive prefetching
- **Prefetching from the World Wide Web**
  - WebSnatcher, Anycasting paradigm
- **Backup and Reliability**
  - Experiments with incremental-only; snapshots
- **Disk System Architecture and File System Issues**
  - NASD, active disks; Data and metadata layout