Open vs. Proprietary Standards

- Open standard – a standard that is well documented, unencumbered by intellectual property rights and restrictions, and available to any vendor.

- What are the advantages?

- What are the disadvantages?

Network Architecture

- Network architectures are layered
- Each layer
  - uses the services of the layers below
  - To offer more advanced services to layer above
- Allows layers to be designed independently
- We will talk about 3 layers next...

Network
Link
Physical
**Network Layer**

- A wants to send some data to C
  - Suppose A knows C’s address
  - A sends a packet towards C
    - A marks his packet with C’s Address (an IP Address)

**Post Office Analogy**

- Bob in New York
  - Alice Smith
    - 1156 High St
      - Santa Cruz 95064
  - Plane to London
  - Plane to SFO
    - Truck to Santa Cruz
    - Truck to Santa Rosa

**Routing in the Internet**

- Many feasible paths from source to destination.

**Routing**

- Updating the routing table
- Objective: each packet gets closer to destination

**Packet forwarding**

- Transmitting each packet on the appropriate output link
- Based on routing table
Routing Algorithms

Routers talk to each other to build their routing tables.

Routing Table has Wild Cards

Internet Routing is Hierarchical

Routing Concerns

- Long routes
- Circular routes
- Hijacking routes
- Route flapping

IP Addresses vs Mac Addresses

- Hierarchical
  - The beginning bits tell you which network the host is on
  - Ex: UCSC addresses start with 128.114.X.X
  - The last bits tell you which host of the network
  - Not Changeable
  - Changes with location of Host
  - 4 bytes
  - Only 4.2 billion

- Not Hierarchical
  - Beginning bits tell nothing useful

- Not Changeable
  - 6 bytes
  - 281 Trillion

Link and Network Layer Interaction
Transport Protocols

- The Internet is unreliable
  - It will make a "best effort" to get your packet to its destination
- Packets can be lost because of
  - Congestion
  - Link errors
  - Routing problems

<table>
<thead>
<tr>
<th>Application</th>
<th>Presentation</th>
<th>Session</th>
<th>Transport</th>
<th>Network</th>
<th>Link</th>
<th>Physical</th>
</tr>
</thead>
</table>

Transmission Control Protocol (TCP)

- Retransmit mechanism for reliability
  - Receiver sends acknowledgements to sender
  - If a packet is lost, source fails to get ACK, and then retransmits.
- Congestion control
  - If congestion perceived (by lost packets)
  - Source reduces its send rate
    - When loss, sender reduces send rate by half
    - Otherwise slowly increases

TCP cont’d

- TCP port numbers
  - TCP Header has a "port" number field
  - Helps host sort out how to route packets to applications

<table>
<thead>
<tr>
<th>IP Header</th>
<th>TCP Header</th>
<th>Payload</th>
</tr>
</thead>
</table>

UDP

- For some applications packet retransmissions are not worthwhile
  - Why?
- For those applications, we use UDP
- UDP is a transport protocol that
  - Does not do retransmissions
  - Does not do congestion control

Congestion Control

- When networks are congested, certain sessions (Source-destination pairs) should reduce offered rates.
  - Today all TCP sessions slow down when they detect packet losses.
  - UDP sessions do not slow down.
- What are some alternative strategies?
  - Have those whose applications aren’t as sensitive slow down more?
  - How would we know which are less sensitive

Pricing within the Internet

- Flat Rate or simple usage based
- Customer pays an ISP
  - Often Flat Rate per month
  - ISP pays a backbone AS
  - Often just flat rate, dependent on access link speed.
  - Sometimes based on total usage
  - Backbone NSPs peer with each other
  - Often for free if they exchange comparable amounts of traffic.
- Overall
  - Internet billing today is much more course grained than telephone billing
Domain Names

IP addresses are inconvenient for people
- 32 bits hard to remember
- 128 bits very hard to remember

Domain names
- e.g. argus.eecs.berkeley.edu
- Easier to remember than IP addresses
- However, we need some way of mapping domain names to IP addresses.

Hierarchy in Addresses vs. Names

Addresses hierarchical in topology
- Maximize "wild cards" and distribute address administration

Names hierarchical in administration
- Single administered organizations often distributed topologically (e.g. ibm.com)

Transport Protocols

- The Internet is unreliable
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OSI Layers

Application
Presentation
Transport
Network
Link
Physical

Internet Protocol (IP), ...
TCP, UDP
Ethernet, Wi-Fi, SONNET, ...
Modulation Schemes: QAM, OFDM, etc...

Some Typical Topologies

Home Network
- Ethernet Switch
- DSL Modem
- Telephone Line (to local Office)

Domain Name System (DNS)

Root Name Server
Berkeley Name Server
EECS Name Server
SoE Name Server
UCSC Name Server

Hierarchy in Addresses vs. Names

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- Maximize "wild cards" and distribute address administration

Names hierarchical in administration
- Single administered organizations often distributed topologically (e.g. ibm.com)
Small/Medium Business

- Ethernet Switch
- T1 Modem
- T1 Line
- Router with Firewall
- Web Site Server

ISP Topology

- Telephone Company
  - Local Office
  - Local Loop
  - Telephone Switch
- ISP Point of Presence
  - DSL Modem
  - Leased Line to NAP
  - To Telephone Network

Network Service Provider

Large E-Business

- Presentation Logic (Assembling Web page)
- Logic Flow of Interaction
- Interconnected with Gigabit Ethernet or other technology
- Web Servers
- Application Servers
- Databases
- Web Caching

- Speed up web page loading by storing previously seen components locally
- http://www.ucsc.edu

Web Caching

- Web Caching

- Cache on Hard Drive

Akamai Case

- Akamai Case
- Web server

- UNIVERSITY OF CALIFORNIA
**Internet Bottlenecks**

- **First Mile** (Server Capacity) - 70% of website performance problems according to one study
- **Backbone** - Plentiful, but some shortage within metropolitan areas
- **Peering** - Exchange of traffic between NSPs
- **Last Mile** to home
  - 56 K modems are slow
  - Shared LAN limitations

**Solutions**

- **Expand Bandwidth**
  - Being done
- **Mirroring web sites**
  - Put exact copy of same web page to multiple servers
  - Tricky to duplicate content
- **Caching**
  - Problem: Stale Content
  - Problem: Hard to count "click throughs"
- **Content Distribution Networks**

**Freeflow**

- **Deployed in 1999**
- **Akamai Infrastructure**
  - 13000 servers in 954 networks by 2001
- **Customers**
  - Large Commercial Websites
- **Revenue model - $2000 per mbps served**
  - (For comparison, normal Internet access cost 500 mbps at time)

**2000 Financials**

- $196 Million Loss (before special charges)
- $90 million revenue
- 520 gross margin, after deducting
  - server depreciation
  - payments to network partners
  - Data center space
  - But, most expenses of shouldn't grow at same rate as number of customers, so margin should improve
- $201.5 million SG&A
  - (selling general and administrative)
  - (largely sales force cost)
  - Again, this might not grow at same rate as the number of customers.
- $40 million R&D

**Competition**

- **Hosting firms (substitute)**
  - Exodus
- **Other CDNs**
  - Sandpiper, Adero, Mirror Image
- **Content Alliances**
  - Akamai’s competitors banded together to share networks
2001 Market Changes

Bad
- Dot-coms bust
- Customers leave
  - "churn rate goes to 22% per quarter"

Good
- Hosting firms go bust (exodus)
- Some CDN competitors go bust.
- Competing CDN alliances mired in problems

EdgeSuite

- Assemble dynamic pages at edges rather than just serve heavy objects
- Value proposition
  - Performance improvement
  - Cost and complexity reduction
  - Scalability
  - Security
- Pricing - higher than old service
- Soon edge suite dominated revenue

Technology

Dynamic CDN technology: ESI (edge sides includes)

Develop as open standard why?
Akamai not big and credible enough to force a de-facto standard on market

Marketing

- Difference in selling old vs new products:
  - Old product
    - Geared toward speeding up websites
    - Revenues of their clients depended on speed
    - Easier to get sale
  - New Product
    - Simplify company IT function
    - Cost vs. revenue center
    - Harder sell. More data driven...
    - Consequently new product needs more professional sales force
- Channels?
  - Distribution Partners (IBM) credibility
  - Direct Sales Force too

Recent Performance