Overlay networks and P2P

1: Get torrent metafile
Torrent

2: Get peers from tracker
Tracker

1: Get torrent metafile
Torrent

2: Get peers from tracker
Tracker

3: Trade chunks with peers
Peer

Unchoked peers
Seed peer
Source of content
Overview

• **Overlay networks**
  – Logical network running on top of physical network
  – Support alternate routing strategies
  – Experimental protocols

• **Peer-to-peer (P2P) networks**
  – Directory-based
  – Unstructured
  – Structured
Internet ossification

• The Internet
  – Originally so researchers to experiment with packet switching
  – Now commercial interests dominate
  – Massive size, can't change software in all the routers

• How to investigate and deploy new features?
  – Migration to IPv6
  – Multicast routing
  – Virtual private networks
  – Optimizing routing between small set of hosts
  – New services such as peer-to-peer
Overlay network
Application level focus
Overlay networks

• Many logical networks may coexist
  – Over same underlying network
  – Each providing its own particular service

• Nodes in overlay network
  – Often end hosts
  – Act as a traffic forwarding agent
  – Provide a service such as file sharing

• Which nodes are in the network?
  – Party providing the service (e.g. Akamai)
  – Collection of end users (e.g. P2P sharing)
Overlay networks

• **Logical network built on top of a physical network**
  – Overlay link is a connection between two nodes
    • Link makes sense from standpoint of the logical network
    • Actual packets on overlay link may transit a series of physical links
  – Internet started as overlay network of the old telephone network
Using overlays for routing

• **Routing overlay**
  – Purely to support alternative routing strategy
  – No application-level processing at overlay nodes

• **Examples:**
  – IPv6
  – Virtual Private Network (VPN)
  – Mobile IP
  – Multicast

• **Relies on creating "tunnels" through the network**
IP tunneling

- **IP tunnel**
  - A virtual point-to-point link
  - A packet gets encapsulated inside another packet
Deploying IPv6

- **6-Bone**
  - Overlay network to support IPv6
  - Tunnels IPv6 packets over routers not supporting IPv6
Creating private networks

• **Virtual Private Networks (VPNs)**
  – A secure private network running over the public Internet
  – Equip each office with a firewall that creates tunnels between all pairs of offices
  – Roaming users can connect to firewall using VPN software
Routing to mobile hosts

• Mobile IP
  – Route packets to a roaming mobile host
  – Home agent tunnels traffic to foreign agent
Delivering to multiple hosts

• **Multicast**
  – Deliver same content to many hosts avoiding redundancy

• **IP multicast**
  – Special addressing, forwarding, and routing
  – Not widely deployed, MBone tunneled between nodes
End-system multicast

- End-system multicast
  - IP multicast not widely deployed, have hosts do it instead
  - End hosts form their own multicast tree
  - Hosts help forward data onto to others in multicast group

Network with link costs.

Multicast with router support.

Naïve delivery using unicast.

End-system multicast, C forwards traffic on to D.
Improving performance

• Resilient Overlay Networks (RON)
  – Build overlay networks between small set of nodes (~10s)
  – Monitor latency, bandwidth and drop probability between every pair of nodes
  – Use data to select optimal route between nodes in set

Sometimes it may be better to take several hops compared to going direct.
RON performance

- **IP routing does not adapt to congestion**
  - RON can reroute when path is congested
- **IP routing is sometimes slow to converge**
  - RON can quickly direct traffic around problem
- **IP routing depends on AS policies**
  - RON can pick best performing path ignoring policies
- **But RON has some drawbacks:**
  - Packets may go through more hops, loading hosts, increasing costs
  - Probing causes network overhead
Overlay services: P2P

• **Peer-to-peer (P2P) networks**
  – Community of users pooling resources (storage space, bandwidth, CPU) to provide a service
  – e.g. Sharing MP3 files, Skype
  – Nodes are hosts willing to share, links are tunnels used to transport objects of interest

• **Types:**
  – Centralized P2P – central server for indexing
  – Pure P2P – all peers are equals
  – Hybrid P2P – some peers are supernodes
P2P: Napster

• **Napster: the rise**
  – Created by Shawn Fanning
    • Christmas break his freshmen year at college
  – Allows people to search and share MP3 files
  – January 1999, Napster version 1.0
  – May 1999
    • Company founded
    • Shawn drops out of school
  – September 1999, first lawsuits
    • No such thing as bad publicity
  – By 2000, 80 million users
P2P: Napster

- **Napster: the fall**
  - December 1999
    - RIAA files lawsuit
  - Metallica's "I Disappear" circulates
    - Before official release, starts getting radio play
    - 2000 band files a lawsuit
  - July 2001, shutdown due to lawsuits
  - 2002, relaunched as a paid service
    - Major record labels not keen to license
    - Files bankruptcy
  - Gave rise to many P2P alternatives
  - Forced industry out of stone age
    - iTunes

Napster technology

• **User installs software**
  – Registers name, password, local directory with music

• **Client contacts central Napster server**
  – Connects via TCP
  – Provides list of music in user's directory
  – Napster updates its database

• **Client searches for music**
  – Napster identifies currently online client with file
  – Provides IP addresses so client can download directly
Napster technology

• Central server continually updated
  – Easy to track music currently available and from what peer
  – Good source to prove copyright infringement
  – Single point of failure, performance bottleneck

• Peer-to-peer transfer
  – Key idea of P2P: heavy lifting done between peers
  – No need for Napster to provision lots of capacity
    • Just enough to support indexing/search needs of clients

• Proprietary protocol
P2P: Gnutella

- **Gnutella**
  - Early 2000, created by Justin Frankel & Tom Pepper at Nullsoft (recently acquired by AOL)
  - Prematurely announced on Slashdot
    - Thousands download client
    - Next day AOL shuts it down over legal concerns
    - Too late, protocol reverse engineered and released as open source
  - Protocol became basis for many clients
    - e.g. Limewire, Bearshare
P2P: Gnutella

• **No centralized object registry**
  – Hosts arrange themselves in overlay network
  – Each host runs Gnutella software

• **Joining the network**
  – Contact a few nodes
    • Pre-existing list shipped with software
    • Web cache of known nodes
  – Send ping to neighbors who ask their neighbors
  – New node gets pong messages back from other nodes
  – Repeat until new node reaches quota of desired neighbors
P2P: Gnutella

- **Query flooding**
  - Client wants some file
  - Sends query to connected neighbors
  - Neighbors send to their neighbors
  - ...
  - Node with file sends response
    - Classic gnutella, response sent along route of the query
    - Client connects to host with file and downloads
    - Or if host is behind a firewall, clients requests host push the file
Gnutella query flooding

• Query over existing TCP connections

• Flooding scalability:
  – Queries have TTL
    • Remove if been around too long
  – Unique query ID
    • Don't forward recent queries

File transfer: HTTP

Client doing search
Gnutella

• **Advantages**
  – Fully decentralized, all nodes are equals
  – Hard to shutdown since no central server
  – Search cost distributed among nodes

• **Disadvantages**
  – Each search may cause a lot of traffic
  – Search time may be long
  – Paths are unreliable with hosts going up and down
P2P: FastTrack

• FastTrack
  – 2001, created by Dutch company (Kazaa BV)
  – Same team that later built Skype
  – Hybrid P2P, uses super-nodes to improve scalability
  – e.g. KaZaA, Morpheus

• Smarter query flooding
  – Join by contacting super-node
  – Client sends list of files to its super-node
  – Search: send query to super-node who floods to other super-nodes
  – Fetch file directly from peer(s)
P2P: FastTrack

• **Supernodes**
  – Indexes users' shares and performs searches on them
  – Normal nodes can get promoted to super-node
    • Selected based on uptime history
  – Consolidate queries since many nodes only have a few files
    • May be faster for super-node to handle than delegating to normal-node
P2P: BitTorrent

• **BitTorrent protocol**
  – 2001, Bram Cohen releases first protocol implementation
  – Now supported by many different clients
  – 2011, ~100 million users

• **Motivations:**
  – Serve up popular content fast
    • Popularity exhibits temporal locality (flash crowd)
  – Efficient fetching, not searching
    • Distribute same file to many peers
    • Single publisher, many downloaders
  – Measures to prevent free-loading
BitTorrent process

• File divided into many pieces
  – Peers exchange the pieces by uploading and downloading to each other
  – Seed, peer with entire file

• Process:
  – Users find a torrent of interest, open in BitTorrent client
  – Client contacts the tracker listed in torrent file
  – Gets list of peers currently transferring the file
    • Swarm – the peers currently with some/all of the file
BitTorrent process

New peer, leech

Get .torrent

Tracker

Peer, seed

Get pieces

Peer, leech

Web page .torrent file

Get .torrent
BitTorrent process

Web page .torrent file

Tracker

Get peer list

New peer, leech

Peer, seed

Get pieces

Peer, leech
BitTorrent process

Web page .torrent file

Tracker

A

New peer, leech

Handshake

B
Peer, seed

Get pieces

C
Peer, leech

Handshake
BitTorrent process

A now starts to receive random pieces of file from seed B and from what C has gotten thus far.

Web page .torrent file

Tracker

A

Get pieces

Pee, seed

B

Get pieces

Get pieces

New peer, leech

A

Get pieces

Get pieces

C

Peer, leech
BitTorrent process

A can now share any pieces it got from B that C hasn't yet received.
Summary

• **Overlay networks**
  – Allow deployment of new routing protocols and services
  – On top of the existing physical internet
  – Much nimbler than relying on upgrades in all routers

• **Applications of overlays:**
  – IPv6 deployment, Mobile IP, Multicast routing
  – Virtual Private Networks (VPNs), Resilient Overlay Networks (RON)

• **P2P services:**
  – Varying degrees of centralization
  – Different target applications