Overlay Networks
A Scalable Alternative for P2P

CS670 – Computer Networks
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Outline

- Introduction to P2P networks
  - Definition
  - Advantages
  - Uses
  - Disadvantages
- Introduction to Overlay Networks
- Internals of Overlay Networks
- An example of Chord
Introduction to P2P

- **P2P – What is it?**
  - P2P stands for Peer-to-Peer
  - It refers to a network that adheres to a philosophy of decentralized collaboration and communication
    - Each node is called a peer; all peers are equal
    - No centralized servers, storage, coordination, or communication

- **How do P2P networks accomplish tasks?**
  - Peer nodes connect directly to other peer nodes
  - Tasks such as searches, reading/writing of data, communication, etc. are performed by contacting the list of “neighbors”
  - Tasks propagate through the network of peers until the data is found or the target node is located

- **What are P2P networks good for?**
  - These networks promise many advantages over traditional client/server systems:
    - Accelerating communication processes [2]
    - Exploiting idle resources [2]
    - Disseminating most recently created and highly distributed information [2]
    - Availability – 24-hour access [3]
    - Durability – Information can last forever [3]
    - Access control – Information is protected [3]
    - Authenticity – Forged documents cannot be substituted for real documents [3]
    - Denial-of-Service resilience – Makes it difficult for DOS attacks to succeed [3]
    - Massive scalability – Supports thousands, millions, billions of nodes [3]
    - Anonymity – Protects users from being exploited/punished [3]
    - Deniability – Users can deny knowledge of data on their machines [3]
    - Resistance to censorship – No one can censor the data once in the system [3]
Introduction to P2P

What are P2P networks good for (cont.)?

- Applicability of P2P ranges over many areas:
  - Distributed file storage
  - Data replication
  - File sharing
  - Communication via message boards [5]
  - Content distribution [5]
  - Publishing websites [5]
  - DNS-type services [4]
  - Cooperative mirroring – Allows a set of web developers to mirror pages of one another that could (at certain times) have high levels of traffic [4]
  - Time-shared storage – Provides storage of data for nodes intermittently connected to the network [4]

Weaknesses of standard P2P

- P2P is a flooding style network
- Limited scalability; potential high network load
- Connections between peers unstructured
  - Content location and network topology are uncorrelated, forcing searches to use flooding with a TTL (time to live)
  - Due to TTL, all content is not necessarily accessible from all nodes
  - The network is random, giving search times of O(N) where N represents number of nodes
- Non-deterministic searches
**Example 1 – Unstructured P2P Network**

![Diagram of unstructured P2P network]

Taken from [1]

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**Introduction to Overlays**

- **What is an Overlay?**
  - A software network topology
  - Organizes the P2P network by content
  - Gives the network a symmetrical, structured layout (rather than a random layout)

- **Advantages over unstructured P2P**
  - Deterministic data retrieval
    - Guaranteed data retrieval [1]
    - Bounded lookup times [1]
  - Automatic load balancing [1]
  - Self-organization [1]
  - Scalability [4]
Overlays – How They Work

- **Deterministic data retrieval**
  - Data is mapped to nodes according to content
  - Uses secure one-way hashing algorithms to obtain fixed-width keys from data
  - Data is distributed to nodes on the network according to where it belongs (see example 2)
  - Since data is organized onto nodes by content, searches are more productive, producing $O(\log N)$ complexity in searches
  - Due to content-mapped data and $O(\log N)$ complexity searches, data can be definitively located in the network (if the data exists, it is found from any node in the network)

- **Automatic Load Balancing**
  - Consistent hashing produces a uniform distribution
  - Since keys are hashed in a uniform way, all nodes in the network receive roughly the same number of keys [4]
  - Additionally, when nodes join or leave the network, key/data pairs are migrated to the appropriate nodes in the network, thus maintaining balance in the system

- **Self-organization**
  - Application-specific algorithms exist to organize the network
  - Chord maintains a pointer to the next node in the chain (the successor), as well as a list of pointers to “finger” nodes for nodes $(n + 2^k)$ with $1 < k < \text{total # nodes}$
  - Chord then runs algorithms periodically to guarantee that all required properties hold true; namely that the successor and finger pointers are valid
**Overlays – How They Work**

- **Scalability**
  - Searches are not flooding style, so load does not increase at a near exponential rate with network size
  - Searches are always bounded to $O(\log N)$ time, allowing for reasonable search times even with large numbers of nodes
  - “The cost of a Chord lookup grows as the log of the number of nodes, so even very large systems are feasible. No parameter tuning is required to achieve this scaling.” [4]

**Example 2 – Structured Overlay Network**

- **A simple example using DNS with Chord [2]**
  - Purpose of DNS is to map host names to IP addresses
  - Host name represents the key
  - IP address represents the value for the key
  - Two hashes calculated using SHA-1 (secure hashing algorithm)
    1. The address of each peer in the network
    2. The host name in order to obtain the true key
  - Host name/IP address pairs are moved to the nodes whose hashed ID precedes the hashed host name key
Example 2 – Structured Overlay Network

Summary

- Unstructured P2P networks provide a great service, although in an undeterministic, unbridled way
- Overlays tame P2P networks into a structured, deterministic pattern such that critical applications can perform well on them
- Overlays provide advantages in:
  - Deterministic searches
  - Bounded search time
  - Content-addressable data
  - Load balancing
  - Scalability
References