Streaming Content Delivery In Peer-to-Peer Networks

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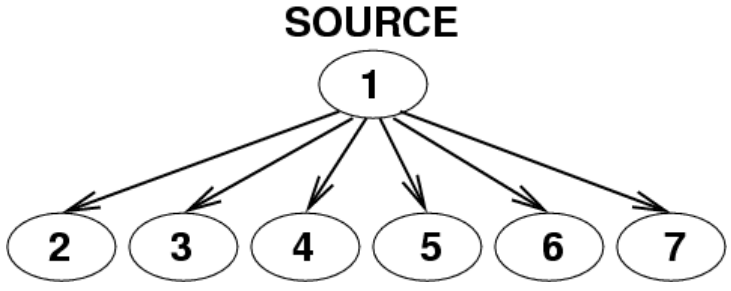
Context: Cooperative Environments

- (Large) computer network
- Participating nodes contribute resources to join the system
- Contributors expect gain proportional to their contribution
  - e.g., incoming bandwidth == outgoing bandwidth
- Highly-dynamic structure
  - nodes come and go all the time
- Examples:
  - peer-to-peer file sharing platforms (BitTorrent, Kazaa, etc.)

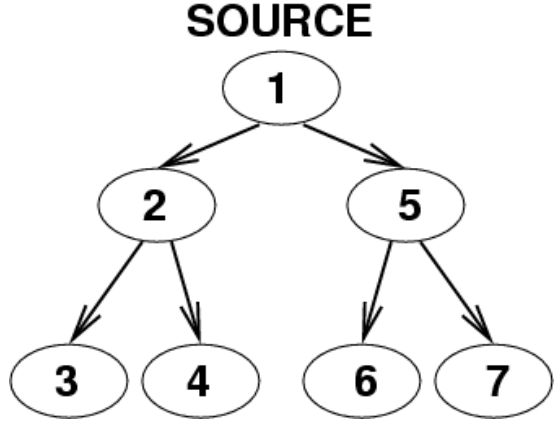
Goal: Multicast

- Multicast: one-to-many
  - single node acts as a content sender (1)
  - multiple nodes receive content (2-7)
  - e.g., video streams, bulk file archives



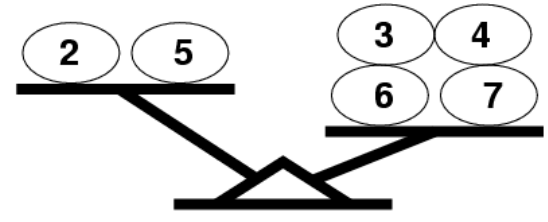
- Many sender-to-receiver connections inefficient
  - **redundancy** (source repeatedly transmits the same data)
  - **physical constraints** (source has limited bandwidth)

- Instead: multicast tree
  - organize nodes into a tree
  - content sender == root (1)
  - internal nodes receive and forward content (2,5)
  - leaves only receive (3,4,6,7)

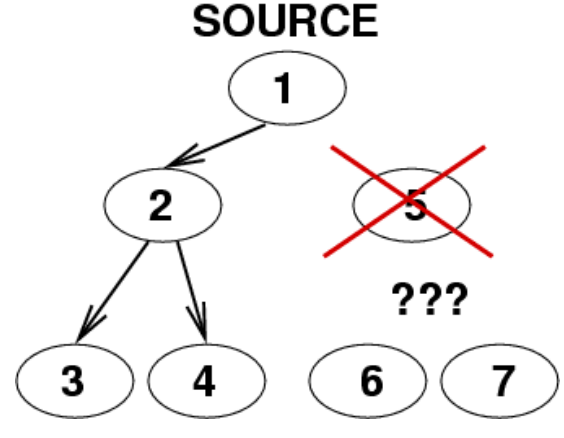


Problem: Cooperative Multicast

- Fundamental conflicts between multicast and cooperative networking:
  - **unbalanced node responsibilities**
    - a few nodes forward, the others just receive



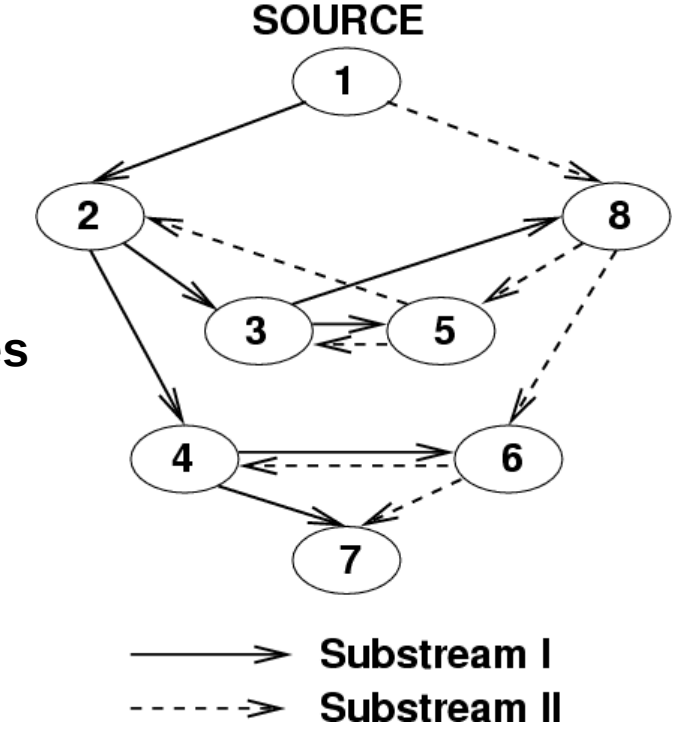
  - **unbalanced contribution and gain**
    - tree-internal nodes: bandwidth contribution >> bandwidth gain
    - leaves: bandwidth contribution == 0
  - **leaving tree-internal nodes spoil the tree**
    - ..and all the nodes below become disabled



- **What can we do about it?**

Solution: Forest Multicast

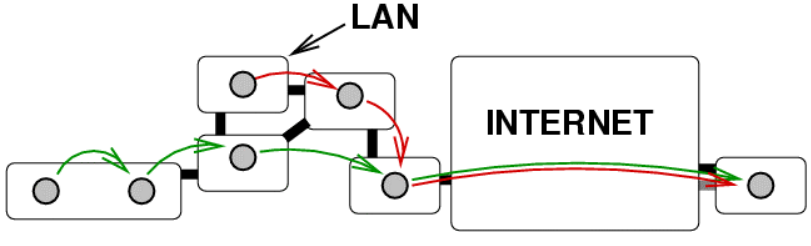
- Forest: multiple multicast trees
  - The original content stream split into **k** substreams
  - All substreams **equally important**:
    - Any m < k substreams give the original stream
    - Erasure Coding, Multiple Description Coding
  - Substream trees have **different internal nodes**
  - Solves single-tree limitations:
    - **Load distribution**
      - different forwarders in different trees
    - **Resilience to forwarder failures**
      - redundant content coding

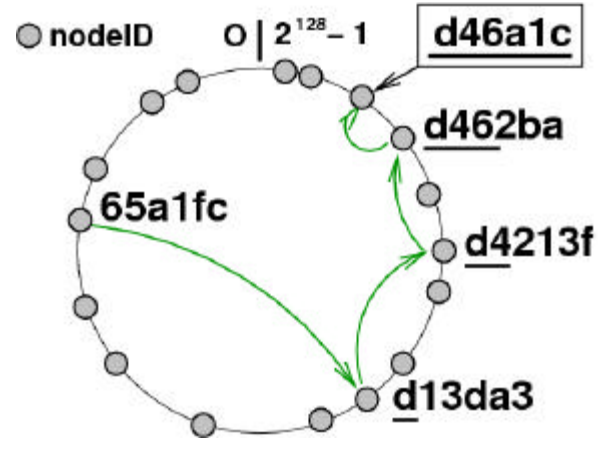


- **How to build a forest of internal-node-disjoint trees?**

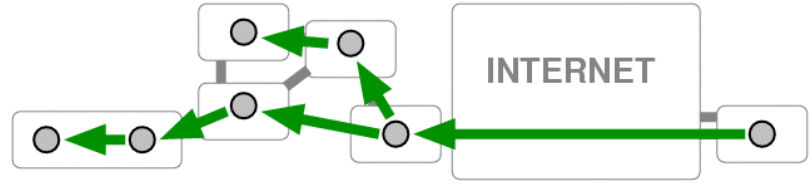
Forest Multicast: Implementation

- Distributed forest construction using Pastry/Scribe
  - Pastry:
    - self-organizing peer-to-peer overlay
    - nodes have random numerical nodeIDs
    - one routing step ~ one digit in target nodeID
    - **low route delay penalty**
    - **local route convergence**



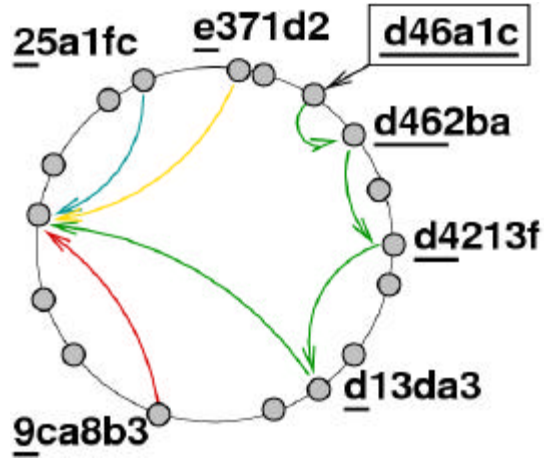


  - Scribe:
    - single-tree multicast over Pastry
    - reverse-path forwarding
    - So: NodeIDs of root and internal nodes have **the same 1st digit**



SplitStream

- SplitStream -- Forest multicast based on multiple Scribe trees
  - Different trees -- **different roots**
  - Different roots -- **different 1st digits** in NodeIDs
  - Scribe:
    - **1st digit the same for root and internal nodes**
  - So: **node can be a forwarder of at most one substream**



- Properties:
  - **global function/load balancing**
  - **resilience to forwarder failures**
  - **higher propagation delay** than in Scribe (more synchronization needed)
  - **uses more network links** than Scribe (multiple trees)
  - ..but **incurs lower per-link load** (less data/stream)

Is SplitStream really that great?

- SplitStream tweaks multicast to work in cooperative environments:
  - **balanced responsibilities and load**
  - **resilience to node failures**

- But it also assumes that:
  - **nodes contribute bandwidth** (otherwise new nodes cannot join)

- Meanwhile, the reality is that:
  - **nodes are not willing to contribute**
    - in 2000, about **70%** of Gnutella users shared no files (and hence no bandwidth)
    - **50%** of all requests were serviced by **1%** of (highly-altruistic) nodes
      [Freeriding on Gnutella]

- So how reasonable is it to rely on node-contributed resources?
- Can we run resource-demanding apps in peer-to-peer systems?