

## Internet Overlay Networks

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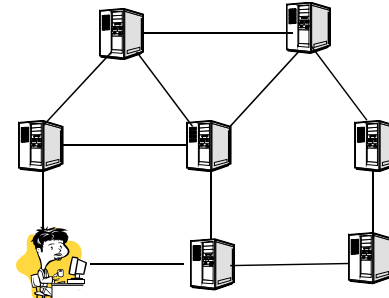
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## Overlay Networks

Overlay networks: A logical network laid on top of the Internet

- nodes are Internet end hosts
- links are virtual Internet paths



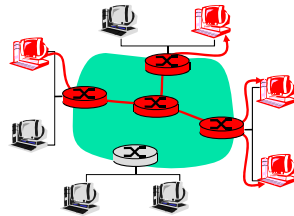
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## Multicast

- **Multicast**: act of sending data to multiple receivers.



Remember the protocols?

Practical problem of network-layer multicast?

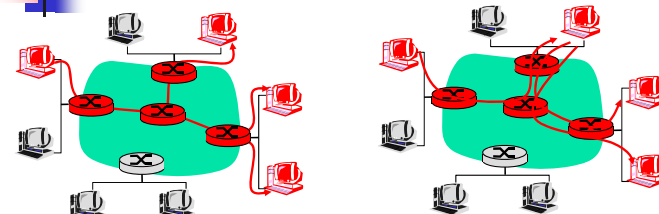
- complicates the router design and implementation; requires routers to maintain per-group state;
- slow to be widely adopted.

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## Network-layer vs. Overlay Multicast



Network-layer multicast

Overlay multicast

- Any better than multiple unicasts?
- Performance issues for overlay multicast
  - Limit the bandwidth consumption of individual physical links
  - Minimize the source-to-end latency

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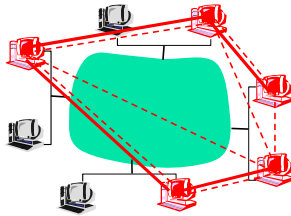
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## Overlay Multicast: One Approach

Two steps:

- Forming an overlay mesh network, don't worry about loops at this step
  - too dense a mesh results in too much overhead in the second step; more probable to have high link stress
  - too sparse a mesh restricts what the second step can do
- For each multicast source, generating a shortest path tree or "reverse-path forwarding" on top of the overlay mesh



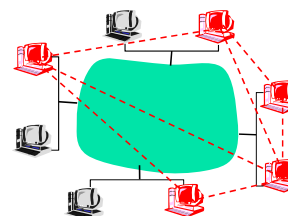
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## Overlay Mesh Network

- Network properties
  - Density
  - Connectivity
  - Real link latency
- Self-maintenance and self-organization
- Node join
  - Add links to some randomly chosen existing members
  - Or some neighbors that are nearby?
- Node departure
  - Break links to departing node
  - Make up with additional links

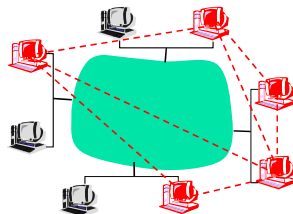


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## Overlay Mesh Network



- How to find a random node on the network (with uniform probability of finding each node)?
  - Random walk
  - Equal probability to visit each neighbor?
    - [Metropolis-Hastings algorithm]

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## Revisit the Concept of Overlay Networks

Overlay networks: A logical network laid on top of the Internet. A "link" in an overlay network is an Internet path between end hosts.

Advantages over networks with physical links:

- can be formed spontaneously
- can be easily maintained and changed

Disadvantage compared with networks with physical links:

- performance

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## Applications to Overlay Networks

- multicast: network conferencing
- peer-to-peer file sharing
- domain name systems
- multi-player interactive games
- files/news/software distribution
- ... ..
- Internet overlay networks = peer-to-peer networks?

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## Multiplayer Interactive Games over Wide-area Networks

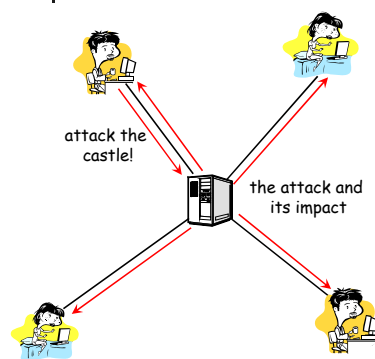
- Some basics:
  - A virtual 2/3-dimensional gaming space with many objects
  - Player-initiated actions: moving your objects, attacking some other objects, etc.
- Main challenges:
  - **Scalability**: supporting many players
  - **Interactivity**: real-time constraint in synchronizing the actions and their impact on the gaming space
  - **Wide-area network**: limited network resources

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## A straightforward way to do it



- A server and multiple client (each for a player)
- All player-initiated actions get to the server and its impact is propagated to all players (with bounded delay)
- Actions can be aggregated when too many come too quickly

What are the potential problems when the number of players scales up?

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## Scalability

- What are the potential problems when the number of players scales up?
  - Computation at the server
  - Network bandwidth connecting the server
- Solutions:
  - multicast
  - distribute the server

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## Distribute the Server

How do we know which server is in charge of a given area?

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## Improves the Internet Routing

- Overlay networks can do beyond enabling new applications
- Possible to improve Internet performance through overlay routing?
  - Triangular inequality doesn't hold for Internet latency
- How to build a real system?
- Practically significant?

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## Improves the Internet Routing

- Little improvement on average, but effective in reducing the chance of very poor network connections
  - E.g., having alternate transport path lowers the chance of disaster from 0.2% to 0.1%
- Internet isn't perfectly robust
  - Routers may fail
  - Default paths may be subject to sudden congestion
- Resilient overlay network [Andersen et al. 2001]
  - Better Internet robustness through overlay routing
- Why can't these robustness measures be put into the Internet routing itself?

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