Data-Driven Overlay Streaming: Design, Implementation, and Experience

IEEE INFOCOM2005
Outline

- Introduction
- Related Works
- Design and Optimization of DONet
- Analysis of Overlay Radius
- Performance Evaluation
- Implementation -- Coolstreaming
- Conclusions
Introduction

- With the wide spread penetration of broadband accesses, multimedia services are getting increasingly popular among users and have contributed to a significant amount of today’s Internet traffic.
- Many multimedia applications, such as NetTV and news broadcast, involve live media streaming from a source to a large population of users.
- For this applications, IP Multicast is probably the most efficient method, but …
Introduction

- Application-layer solutions.
  - Tree structure
    - As the autonomous overlay nodes can easily crash or leave at well, a tree is highly vulnerable.
  - Mesh and Forest structure
    - Much more complex and less scalable.
  - Data-centric design
    - The availability of data guides the flow directions.
    - More suitable for overlay with high dynamic nodes.
Introduction

- DONet (Data-Driven Overlay Network)
- The core operations in DONet are very simple:
  - Every node periodically exchanges data availability information with a set of partners, and retrieves unavailable data from one or more partners, or supplies available data to partners.
Introduction

Three salient features

- Easy to implement
  - It doesn’t have to construct and maintain a complex global structure.

- Efficient
  - Data forwarding is dynamically determined according to data availability while not restricted by specific directions.

- Robust and resilient
  - The partnerships as well as the periodically updated data availability information enable adaptive and quick switching among multi-suppliers.
Related Works

- **Proxy-assisted**
  - A set of servers or application layer proxies are strategically placed.

- **Peer-to-peer based**
  - Tree-based
  - Gossip-based
Design and Optimization of DONet
Design and Optimization of DONet

- Membership manager
  - Helps the node maintain a partial view of other overlay nodes.

- Partnership manager
  - Establishes and maintains the partnership with other nodes.

- Scheduler
  - Schedules the transmission of video data.
For each segment of a video stream, a DONet node can be either a receiver or a supplier, or both.

The video source, which is always a supplier, and is referred to as the original node. It could be a dedicated video server, or simply an overlay node that has a live video program to distribute.
Node Join and Membership Management

- Each DONet node has a unique id, and maintains a membership cache (mCache) containing a partial list of the identifiers for the active nodes in the DONet.
- In a basic node joining algorithm, a newly joined node first contacts the origin node, which randomly selects a deputy node from its mCache and redirects the new node to the deputy.
- The new node can then obtain a list of partner candidates from the deputy, and contacts these candidates to establish its partners in the overlay.
Design and Optimization of DONet

- Node Join and Membership Management
  - Each node periodically generates a membership message to announce its existence.
  - Message format: \(<\text{seq\_num, id, num\_partner, time\_to\_live}>\)
  - Upon receiving a message of a new seq\_num, the DONet node updates its mCache entry for node, or create the entry if not existing.
  - The format of mCache is \(<\text{seq\_num, id, num\_partner, time\_to\_live, last\_update\_time}>\).
Design and Optimization of DONet

- Buffer Map Representation and Exchange
  - Neither the partnerships nor the data transmission directions are fixed in DONet.
  - A video stream is divided into segments of a uniform length, and the availability of the segments in the buffer of a node can be represented by a Buffer Map.
  - Each node continuously exchange its BM with the partners, and then schedules which segment is to be fetched from which partner accordingly.
Scheduling Algorithm

- Given the BMs of a node and its partners, a schedule is to be generated for fetching the expected segments from the partners.
- For a homogeneous and static network, a simple round-robin scheduler may work well, but for a dynamic and heterogeneous network, a more intelligent scheduler is necessary.
Design and Optimization of DONet

- **Scheduling Algorithm**
  - The scheduling algorithm strikes to meet two constrains:
    - The playback deadline for each segment
    - The heterogeneous streaming bandwidth from the partners.
  - The problem is a variation of the parallel machine scheduling, which is known NP-hard.
  - Basic idea:
    - Among the multiple suppliers, the one with the highest bandwidth and enough available time is selected.
Design and Optimization of DONet

- Failure Recovery
  - Graceful departure
    - The departing node should issue a departure message, which has same format as the membership message, except that num_partner filed is set to -1.
  - Node failure
    - A partner that detects the failure will issue the departure message on behalf the failed node.

- Partnership refinement
  - Each node periodically establish new partnerships with nodes randomly selected from its mCache.
Analysis of Overlay Radius
Analysis of Overlay Radius

- The radius of DONet is the average distance for delivering a segment from the origin node to all destinations.
- The analytical result reveals a logarithmic relation between the overlay radius and its size, implying that DONet can scale to large networks yet with limited delay.
- \( D < \log_{M-1} N + 3 \)
Performance Evaluation

- Design of the experiment system
Performance Evaluation

- Performance under stable environment

![Graph showing performance evaluation under stable environment.](image-url)
Performance Evaluation

- Performance under stable environment

![Graph showing performance evaluation](image)
Performance Evaluation

- Performance under dynamic environment
Performance Evaluation

- Performance under dynamic environment
Performance Evaluation

- Comparison with Tree-based overlay
Performance Evaluation

- Comparison with Tree-based overlay
Performance Evaluation

- Comparison with Tree-based overlay

Graph showing the comparison of DONet and Tree-based overlay over time.
Implementation -- Coolstreaming
Coolstreaming

The graph shows the number of users and the continuity index over time. The number of users increases significantly from 18:00 GMT to around 21:00 GMT, while the continuity index remains relatively stable until late evening, when it drops sharply.
Conclusions

- DONet doesn’t maintain an explicit overlay structure, but adaptively forwards data according to data availability and demanding information.
- DONet enables efficient streaming for medium- to high-bandwidth contents with low control overhead.