The missing component for TV-like service over the Internet is a SCALABLE ONE-TO-MANY DISTRIBUTION MECHANISM that accommodates live streaming content.

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the application on their desktop computers with no special support from the network.

Here, I review the key design challenges and explore mesh-based P2P streaming as a promising approach for providing this service. The key role of end systems in content delivery introduces several challenges in designing P2P streaming mechanisms:

Bandwidth heterogeneity and asymmetry. Participating peers in a session are likely to have heterogeneous-access-link bandwidth. The access-link bandwidth of individual peers is often asymmetrical, that is, the incoming bandwidth is greater than the outgoing bandwidth. The heterogeneity and asymmetry of access-link bandwidth imply that various connections of the overlay are likely to have different bandwidth. Therefore, a high-bandwidth peer may need to simultaneously receive streaming content from multiple peers in order to obtain the desired streaming quality.

Dynamics of peer participation (churn). Participating users in a P2P system (and thus their computers) may join or leave a session at any arbitrary point in time. These user-driven dynamics result in ongoing changes of the overlay topology that could disrupt the streaming-content delivery through the overlay.

Utilization of available resources. While the aggregate available resources scale with the user population, the system's ability to utilize available resources may not scale proportionally for two reasons: The structure of the overlay may prevent some peers from contributing their outgoing bandwidth; for example, leaf peers in a tree-shaped overlay do not forward content to other peers. And participating peers may lack sufficient useful content to fully utilize the available bandwidth to their connected peers.

Mesh-Based P2P Streaming

The recent success of BitTorrent, a P2P file distribution protocol, has inspired a new and promising approach to P2P streaming called mesh-based, or data-driven, P2P streaming. In mesh-based P2P streaming, participating peers form a randomly connected mesh-shaped overlay and incorporate swarm-like content delivery similar to BitTorrent [6]. This approach overcomes all three challenges—bandwidth heterogeneity, peer dynamics, and resource utilization—outlined earlier, accommodating delivery of good-quality streams to a large number of users.

Having multiple neighbors enables each peer to gracefully cope with the departure of any of them due to churn. Accommodating bandwidth heterogeneity implies that the quality of the delivered stream to each peer should be proportional to its incoming access-link bandwidth. Each peer could determine the number of its neighbors proportional to its incoming bandwidth to achieve proper bandwidth connectivity to the overlay.

An elegant approach to facilitating bandwidth heterogeneity involves encoding a video stream with Multiple Description Coding (MDC). An MDC encoder organizes a video stream into multiple substreams in which each of them can be independently decoded to produce a low-quality version of the video [5]. Decoding several unique descriptions leads to progressively better quality. With MDC-encoded content, a low-bandwidth user may receive only one description of the video and view only a low-quality version of the video, while a high-bandwidth peer receives all descriptions of the video and views the maximum quality. While MDC provides the flexibility to accommodate bandwidth heterogeneity among peers, the content-delivery mechanism must still ensure that each peer receives a proper number of descriptions.

In swarm-like content delivery, the source provides various segments of that content to at least one peer in the session; participating peers can thus exchange their available segments until each one has the segments it requires. Swarming couples push-content reporting with pull-content requesting. Each peer periodically reports its newly available content segments to all its neighbors while requesting specific new segments from each of them. The segments requested by each peer from a neighbor are determined by a packet-scheduling algorithm based on the available content and bandwidth from