Multicast vs. P2P for Content Distribution

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Abstract:

Content Distribution is originally an application developed for multicasting. Multicasting provided an efficient transport mechanism for one-to-many and many-to-many distribution of the content. The evolution of Peer-to-Peer networks (P2P) has made content distribution more scalable, reliable and resilient than multicasting without requiring a new architecture. This paper briefs the architectural designs of both the systems and argues that P2P is a better alternative to multicasting for content distribution.

1. Introduction:

Frequently many users want to access the same information for an example an audio or video file. Thus distribution of information (content) to many users has become a part and parcel of today's internet world. Content Distribution is widely implemented using two methods namely *multicast* and *peer-to-peer*. Multicast method has a long history whereas peer-to-peer is relatively a new one.

1.1 Multicast method:

Multicasting is based on the traditional client-server architecture for sending the multicast content to users. The server sends the multicast content to the router which replicates the information to all other clients requesting the multicast content (as shown in Figure 1 and Figure 2). The router creates a copy whenever a node requests the server for the information thus utilizing lesser bandwidth than unicasting the data. The router used should be enabled with a multicast routing protocol such as IGMP, PIM etc. All LANs such as Ethernet and many ISP's like Sprint, Naino and Worldcom [1] provide support for multicasting. Multimedia tele-conferencing, distributed database systems, factory automation and many distributed gaming applications make use of multicasting. Multicasting on the World Wide Web is implemented using the MBone, the multicast backbone for multicast traffic.

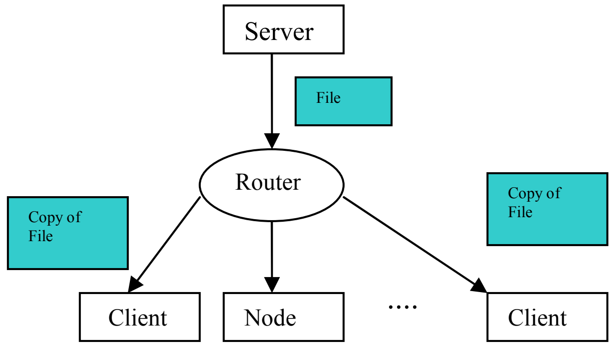

Figure 1- One-to-Many Multicasting

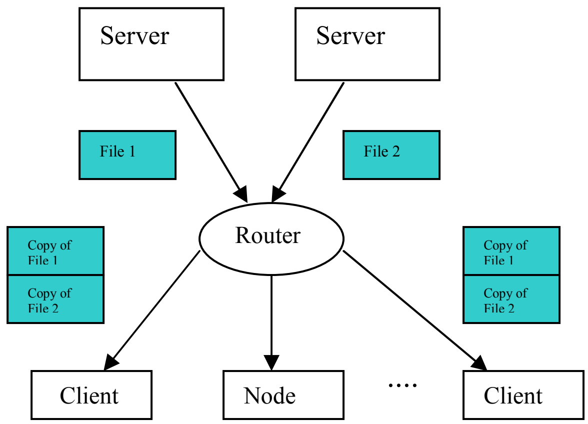

Figure 2- Many-to-Many Multicasting

1.2 Peer-to-Peer method:

P2P is a fully distributed system as every node can act as a client as well as a server. Here each node is called a *peer*. Content upload and download takes place at all the peers. P2P is widely used by many applications like Bittorrent, Freenet, Napster, Gnutella, OpenNAP, CAN, KaZaA, Tapestry, Chord, Pastry and JXTA [2]. The Peer-to-Peer networks can be classified as hybrid, decentralized, structured, or unstructured depending on the role of the peer and existence of a central server. The earlier versions of P2P networks tend to be more hybrid and unstructured (eg. Napster and gnutella) while the modern ones are more decentralized and structured as shown in Figure 2 (eg. Tapestry, Chord and Pastry). A P2P network which has a centralized indexing with distributed file transfer is called hybrid (eg. Napster, KaZaA). A P2P network is called decentralized if there is no central server and all functionalities like searching for files are performed by peers. A structured P2P does not establish links to peers arbitrarily (eg. CAN) where as an unstructured one does. Gnutella is an example of a decentralized and unstructured Peer-to-Peer. The goal of the Peer-to-Peer system is to utilize the resources such as bandwidth, storage space and computing power of all peers.

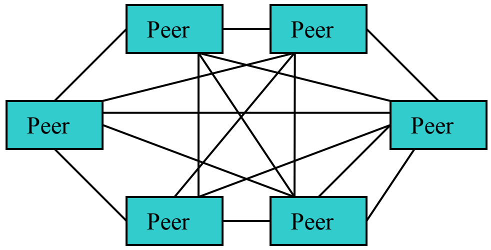

Figure 3- A Decentralized and Structured P2P Network

1.3 Configuration for content replication:

Content replication in multicasting and peer-to-peer require some pre-configuration which is explained below.

1.3.1 *Multicasting:*

Mostly IP multicast is used for replication of content in multicasting. Each replicating node is configured with the same multicast address. All multicast clients are then part of the same replication cluster.

1.3.2 *Peer-to-peer:*

Each peer is configured with the IP address of one other peer. As long as there is a chain of peers linking all nodes together, then a Replication cluster is established. Then unicast communication mechanism is used for discovery.

2. Basis for comparison of multicast and peer-to-peer:

Scalability, reliability and resilience are often considered as the important attributes of content distribution. The main factors affecting scalability are the routing table memory space requirement, architectural change requirement and supporting bandwidth. Reliability depends on how well the system implements the error correction and detection mechanisms with delay-jitter control ability. Resilience is an important attribute which measures the system's quality to remain stable at times of failure of nodes. By comparing both the systems by these qualities we can get a clear idea about which system is more efficient. This idea is discussed in detail in the next section.

3. Peer-to-Peer content distribution as a better alternative:

This section provides the reasons for considering P2P as a better choice than multicasting for content distribution by analyzing different issues relating to the attributes of content distribution. The following part of the section is organized as issue statement proceeded by how the issue is addressed by multicasting and then peer-to-peer systems.

3.1 Scalability:

Scalability is defined as the adaptability to changes in the system size. Now we look at the memory, architectural and bandwidth issues created by scaling the networks.

3.1.1 Routing table memory space requirement:

This part of the section addresses the issues related to memory space requirement for routing table by estimating the number of entries. The multicast routers have to maintain the information of the network as well as the multicast group information. The multicast group information consists of information related to the clients requesting multicast content, interface on which the multicast content arrives and the interface on which it has to be forwarded. For maintaining all the information router requires more memory space. The memory space requirement gets increased whenever new multicast clients request content from the server. The number of entries in the routing table is approximately the product of number of multicast groups and number of senders for PIM [4].

Scalability in peer-to-peer networks is improving from the first generation to second generation. Gnutella, a first generation peer-to-peer network routes by flooding. Thus Gnutella does not scale since the network tends to fill up with messages. The routing table size for Gnutella is equal to number of neighbors of the peers as they flood messages to the neighbors. The second generation P2P networks like chord, based on distributed hash table scale well and use a reduced routing table size to log of the number of peers [5].

3.1.2 Architectural changes:

Large scale networks for content distribution in multicasting is difficult to implement since it has the requirement of enabling the multicast protocol at the routers and running the same protocol among all autonomous systems. For multicast to work properly every layer 3 device in the path from the source to the receiver should be configured properly even if one link is not configured properly the multicast traffic may not be received. Thus it requires a common architecture. Enabling multicast on all the backbone routers could reduce the overall throughput of the network so many ISP's have not enabled multicasting on their backbone routers.

P2P does not require a common architecture at the lower layers of the network since the users can communicate with each other by just installing the client program at the application layer. The open architecture of peer-to-peer networks allows further improvement in scalability which is lacking in multicasting.

3.1.3 Bandwidth:

Over the years efficient use of bandwidth has been the main interest for content distribution. MBone has a bandwidth ceiling of 500 Mbps which cannot handle more than four simultaneous videoconferencing sessions or eight audio sessions. The available bandwidth at one time for a multicast community is 500 Kbps [8].

Peer-to-peer exploits the uploading bandwidth of all the peers thus distributing the cost of bandwidth utilization among all the peers. Peer-to-peer applications can do several things in optimizing the internet bandwidth such as data caching and also controlling usage is also becoming a part of many peer-to-peer applications.

From the discussion, we are able to clearly see that the routing table memory space requirement is much higher in multicasting than in P2P as the networks scale. Peer-to-Peer also has an advantage of open architecture where anyone can create a new application which leads to a healthy competition among the applications. Bandwidth usage multicasting does not seem to be as efficient as peer-to-peer applications.

3.2 Reliability:

Reliability is a measure of transmission of the content in a lossless and sequential manner. Contents of certain applications like video conferencing may be sensitive to jitter. Thus error correction, error detection and delay-jitter are the issues related to reliability.

3.2.1 Error detection and correction:

Ensuring reliable transmission is harder to implement in large scale multicasting. Here we discuss few error detecting and correcting mechanisms commonly deployed in multicasting. One technique that reduces the amount of data repair is forward error correction code in which when many receivers lose one data packet then only that packet needs to be sent. While scaling to large noisy networks, FEC alone does not work since same redundant data might be lost multiple times. Cyclic best effort combined with FEC [9] could overcome this problem but creates another problem of consuming more bandwidth. Another possible solution is receiver initiated error recovery mechanism like Negative Acknowledgement. NACK based approach also does not scale well as large number of receivers may detect packet loss and send NACK to the sender. This is called NACK implosion [6].

On the other hand, peer-to-peer networks work on unicast based mechanism where reliable data transfer is handled by the underlying TCP using error detection and correction mechanisms like sliding window, FEC, etc. Thus scaling does not hinder reliable transmission in peer-to-peer networks.

3.2.2 Delay-jitter:

Multicasting has to serve many receivers on links whose bandwidths vary widely. Thus the underlying network should support constant data rate with less end-to-end delay and jitter. Satisfying these constraints is beyond the scope of multicast protocols [11] since it depends more on the underlying network.

Peer-to-peer networks handle delay sensitive applications by imposing the following constraint*: the uploading bandwidth of a peer cannot be utilized to upload the content until it has finished downloading that content* [10]. This sets up the rate as a constant. Thus the sharing design of peer-to-peer networks works efficiently for a delay sensitive application.

Reliability in peer-to-peer has an edge over multicasting because of the underlying unicast mechanism. Mechanisms used by multicasting does not scale whereas P2P can scale. Delay sensitive applications are more efficiently handled by peer-to-peer networks.

2.3 Resilience:

Resilience is often considered as the ability of the system to cope with the failure of nodes.

2.3.1 Failure of nodes:

Multicasting depends mainly on the server and the replicating multicast router for content distribution. If the router or server fails the whole of multicasting gets affected. Router failure can be recovered only when a new path containing a path with multicast supporting layer 3 device is found.

Peer-to-peer systems are fully distributed thus yield some degree of resilience to failure. If a piece of data is distributed from 10 to 100 peers then the data remains available if one node remains operational. The total number of peers that contain the data will determine the level of resilience. The probability that the data content is available in only one peer is very less hence that scenario has not been considered here.

Thus peer-to-peer systems can handle node failures more effectively than multicasting as the content is inherently distributed among many peers.

4. Conclusion:

This paper presents an overview and comparison of the two main systems available for content distribution namely multicasting and peer-to-peer. The comparisons indicate that peer-to-peer are more efficient than multicasting for content distribution. Today P2P networks are widely used by masses on the wide area content distribution rather than MBone. Bittorent is a very good example for that as it is being frequently used for distributing files.

5. References:

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