Design of High Performance Middleware for Dynamic Peer-To-Peer Networks

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Abstract*—This paper deals with a specially designed middleware (P2P Messaging System) that release the advantages of peer-to-peer networks to a broad spectrum of applications. The goal of this paper is to design a middleware for p2p networks that focuses on high-performance group communication based on a publish/subscribe model and its performance is compared with the JXTA technology. The P2P Messaging System considers the heterogeneous and dynamic character of peer-to-peer networks by an augmented topology and its supporting features. This paper gives a solution for an efficient group communication that is established by creating an Overlay networks to overcome topological limitations, implementing the Multi-ring topology to provide scalability, heterogeneity of Peers and decentralization, creation of Dual mode links to allow multiple message sources and to avoid message collisions and creation of Backup links to increase robustness.

***Index Terms*—Peer-to-Peer, Domain Name Server, World Wide Web, Over lay networks**.

I. INTRODUCTION

Recently, the peer-to-peer (P2P) paradigm for building distributed applications has gained attention from industry and the media as well as scientific communities. Peer-to-peer systems can be characterized as distributed systems in which all nodes have same capabilities and responsibilities and all communication are symmetric. Peer-to-Peer (P2P) technology enables any network-aware device to provide Services to another network-aware device. A device in a P2P network can provide access to any type of resource that it has at its disposal, whether documents, storage capacity, computing power, or even its own human operator. In the same manner that the Internet provides domain name lookup (DNS), World Wide Web, email, and other services by spreading responsibility among millions of servers, P2P has the capacity to power a whole new set of robust applications by leveraging resources spread across all corners of the Internet. Emerging systems demand efficient group communication mechanisms that go beyond global peer to-peer communication, which simply forwards messages to all available peers.P2P has the capability of serving resources with high availability at a much lower cost while maximizing the use of resources from every peer connected to the P2P network.

Whereas client/server solutions rely on the addition of costly bandwidth, equipment, and co-location facilities to maintain a robust solution, P2P can offer a similar level of robustness by spreading network and resource demands across the P2P network. Despite these rich possibilities, peer-to-peer applications beyond file sharing are still rare. The reasons are not only the popularity and omnipresence of Web-based services, but also the lack of peer-to-peer enabling technologies. Most of the Companies cannot afford the lengthy and costly development of their own peer-to-peer infrastructure. Due to the rapid application development and short time-to-market requirements in the field of communication, middleware products are needed. CORBA, EJB, COM+, and various messaging systems ease the development of distributed applications, but they do not incorporate features needed for decentralized peer-to-peer environments.

One of the most advanced is JXTA technology an open-source peer-to peer platform managed and mostly developed by Sun Microsystems. Unlike first-generation peer-to-peer networks, which are tied to a specific application, JXTA provides a general- purpose platform targeted to meet the requirements of numerous applications. However, JXTA is still in the maturing process and leaves room for improvement: besides changing networking protocols and stability issues, there are also concerns on performance and scalability.

The P2P Messaging System presented here focuses on group communication in which a group comprises peers with a specific common interest within the network. We assume group communication especially relevant for peer-to-peer applications, because the focus shifts from the individual network node toward a group of nodes. The potential of peer-to peer technology lies in the collaboration of several peers, allowing each peer to profit from others. As collaboration of a group usually requires communication among its members, there is a need for peer-to-peer group communication. Consequently we believe a middleware tailored to this purpose would improve the development process and peer-to peer applications themselves significantly.

Besides the reduced development time, the product's quality may also depend on reliability, performance, and functionality offered by a middleware product.

The peer-to-peer middleware that is to be build should satisfy the following challenges:

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Shared environment: Many independent applications that have different requirements can interfere with each other by means of this middleware.

Scalability: The large number of nodes within a peer-to-peer network may affect performance, latency, and reliability.

Dynamic network: Nodes are unreliable because they may join or leave the network at any time.

Dynamic node characteristics: Since nodes are autonomous, their characteristics may change. For example, concurrent applications may decrease the available bandwidth of nodes.

Network heterogeneity: Each peer is unique according to its networking and computing power, location in the physical network, and provided services.

Quality of service: Given an unpredictable network, the quality of network-dependent services might not be guaranteed but improved.

Security: The middleware should be resistant to malicious peers.

Peer-to-Peer middleware is still an open and emerging topic, and thus a final review cannot be given yet. Consequently, we exemplarily present current solutions and outline a possible model for integrating centralized and decentralized systems.

II. MATERIALS AND METHODOLOGY

Regrettably, the current applications of P2P tend to use protocols that are proprietary and incompatible in nature, reducing the advantage offered by gathering devices into P2P networks. Each network forms a closed community, completely independent of the other networks and incapable of leveraging their services. Until now, the excitement of exploring the possibilities of P2P technology has overshadowed the importance of interoperability and software reuse. To evolve P2P into a mature solution platform, developers need to refocus their efforts from programming P2P network fundamentals to creating P2P applications on a solid, well-defined base. To do this, P2P developers need a common language to allow peers to communicate and perform the fundamentals of P2P networking. Realizing this need for a common P2P language, Sun Microsystems formed Project JXTA which is an existing system that is to be compared with the P2P Messaging System.

2.1 JXTA Protocols Specification

The JXTA Protocols Specification defines the basic building blocks and protocols of P2P networking:

Peer Discovery Protocol—Enables peers to discover peer services on the network.

Peer Resolver Protocol—Allows peers to send and process generic requests.

Rendezvous Protocol—Handles the details of propagating messages between peers.

Peer Information Protocol—Provides peers with a way to obtain status information from other peers on the network.

Pipe Binding Protocol—Provides a mechanism to bind a virtual communication channel to a peer endpoint.

Endpoint Routing Protocol—Provides a set of messages used to enable message routing from a source peer to a destination peer.

The JXTA protocols are language-independent, defining a set of XML messages to coordinate some aspect of P2P networking.

JXTA Core Building Blocks

Peer Groups

A peer group is a collection of peers that have agreed upon a common set of services. Peers self-organize into peer groups, each identified by a unique peer group ID. Each peer group can establish its own membership policy from open to highly secure and protected. Peers may belong to more than one peer group simultaneously. Peers may elect to join additional peer groups.

Peer Pipes

Peer pipes are used to send the data's or other contents to other peers. The messages the are send through pipes to each peers are in the form of XML format. Security issues are provided with each pipe.

Peer Monitoring

The Peer Monitoring checks the peer status remotely and controls the remote peer behavior. It is used to set the usage or bandwidth limits

Security

The Pluggable architecture supports a variety of standard Security solutions. It has certain Control group memberships. The data's send over pipes are encrypted.

Network Services

Peers cooperate and communicate to publish, discover, and invoke *network services*. Peers can publish multiple services. Peers discover network services via the Peer Discovery Protocol. The JXTA protocols recognize two levels of network services:

Peer Services

A peer service is accessible only on the peer that is publishing that service. If that peer should fail, the service also fails. Multiple instances of the service can be run on different peers, but each instance publishes its own advertisement.

Peer Group Services

A peer group service is composed of a collection of instances of the service running on multiple members of the peer group. If any one peer fails, the collective peer group service is not affected. Peer group services are published as part of the peer group advertisement.

As JXTA is a general network, it has to separate peers of a common application. This is done using peer groups. The"NetPeerGroup" is a special group that all peers belong to. Nevertheless, peers may participate in any number of other groups. There is also a group authorization mechanism evolved, which can be extended to provide one that fulfills individual needs.

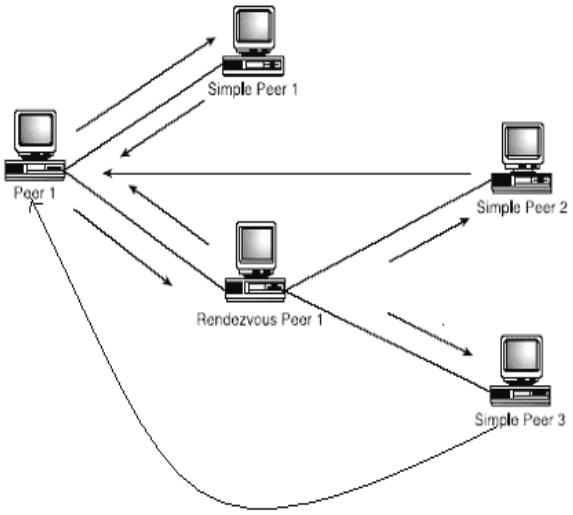

Figure 1. Peer services

Each resource, like peers, peer groups, and data resources, is made available by publishing advertisements. Peers may look up these advertisements by sending discovery messages. The common communication practices are "pipes," which hide the message delivery by the peer-to-peer network from users. The delivery includes routing through the peer nodes, and adjusting the route due to node failures. JXTA differentiates between input and output pipes, and between unicast and multicast communication. JXTA provides a network-programming platform specifically designed to be the foundation for peer-to-peer systems. The technology stays away from APIs and remains independent of programming languages. This means that heterogeneous devices with completely different software stacks can interoperate through JXTA protocols. JXTA technology is also independent of transport protocols. It can be implemented on top of TCP/IP, HTTP, Bluetooth, Home- PNA, and many other protocols.

2.2 The P2P Messaging System

The goal of this paper is to d3sign the P2P Messaging System which provides a scalable, robust, and fast middleware suited for Peer-to-Peer applications. It supplies message-oriented group communication based on the Publish/Subscribe model. This model is usually based on topic-based groups, which consist of Publishers and Subscribers. Group members can be Subscribers, Publishers, or both. Messages are sent by Publishers and are delivered to all Subscribers. In the P2P Messaging System, a peer can become a member of any number of groups in order to send and receive messages. A fundamental concept of the system is its multi-ring topology. Although the presented group communication concepts can be used by themselves, the intention is to collaborate with existing Peer-to-Peer networks like JXTA. This symbiosis allows usage of existing Peer-to-Peer middleware functionality while providing a Publish/Subscribe service to Peer-to-Peer applications. The actual message delivery is realized by an infrastructure, which is set up dynamically and Independently from existing middleware.

Overlay Networks

The independent virtual overlay networks are created to overcome the limits of the peer-to-peer network. The multi-Ring topology is suited for the new overlay network. The figure shows a peer-to-peer network, in which the highlighted peers have subscribed to a topic.

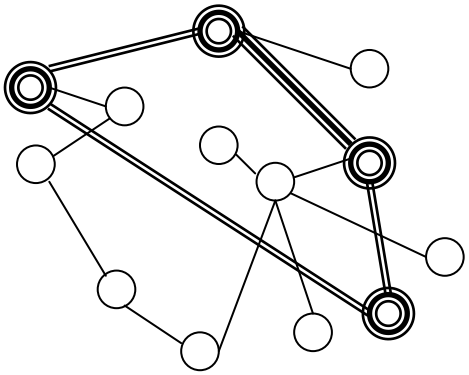

Figure 2. Peer Group Layers

Among these connected peers, an additional overlay network (highlighted links in the figure) for the group is constructed. The peer-to-peer network is not replaced, but complemented by multiple group-based overlay networks, which provide an efficient group communication infrastructure. The solution is based on a topic centric application layer multicasting, which takes care of Quality-of-Service parameters directly. Building overlay networks for each topic makes the message delivery independent from the peer-to-peer network and overcomes its constrains.

Group Communication

By focusing on group communication, the P2P Messaging System provides several functional and conceptual advantages. In a peer-to-peer network, each node is considered a peer that has at least one connection to other peers. We assume application-dependent needs for communication among certain peer groups because the peers forming a group are usually spread randomly within the network. Efficient group communication is a nontrivial task as the location and number of participants is not known.

Multi-Ring Topology

A ring topology is one possibility to build an overlay network. Rings are scalable in means of bandwidth, because the workload of nodes is independent of the total number of nodes *n*. Each node is connected to two neighbors. When a node receives a new message from one neighbor, it forwards the message to its other neighbor. However, slow nodes limit the throughput of succeeding nodes in heterogeneous networks. This is due to the high dependency between the nodes; messages can be forwarded only as fast as they are received from the neighbor node.

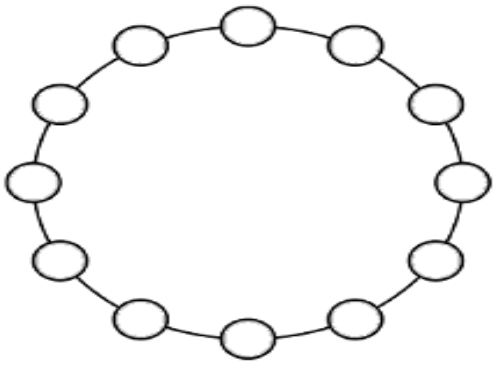

Figure 3. Ring topology

Rings are easy to manage in a decentralized environment, because a node depends only on its neighbors. They are robust for two reasons. Firstly, messages can be sent in two directions. If a node fails or is delayed, its neighbors are not cut-off, because they will still get the message from the other direction. Secondly, establishing backup and repair procedures is relatively easy due to the ring's manageability and simplicity. The fundamental idea is to form additional inner rings based on powerful nodes Each node in an inner ring remains a participant in the outer rings.

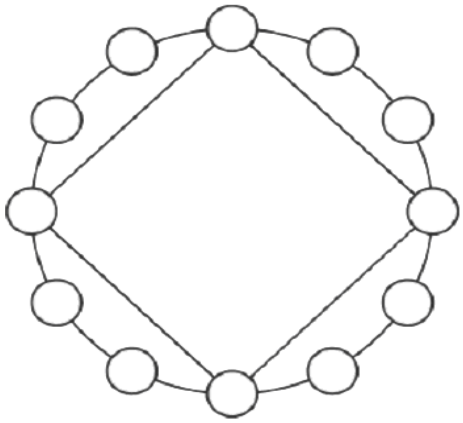

Figure 4. Outer and inner Rings

The proposed multi-ring topology utilizes additional links between the nodes to decrease latency and to connect fast nodes together directly. These additional links introduce redundancy as the same data may arrive from several different sources. To avoid the overhead that would result, we propose the concept of primary and secondary links. In this case, we refer to unidirectional links with a sender node and receiver node. Bi-directional links consist of two unidirectional links. Each unidirectional link has a mode: primary or secondary. The sender node of a primary link sends data immediately to the receiver node, while a sender node of a secondary link first announces the availability of data to the receiver node and waits for the answers whether the data should be sent. This concept considers that there is a specific route, which is preferred over others because it is faster. This route typically consists of primary links, while other routes include secondary links.

Implicit Dynamic Routing

Messages may arrive from several sources, especially when inner rings are involved. This improves overall stability because node failures may be compensated by alternative routes. However, it may also cause wasting network traffic as messages might be delivered to nodes more than once. The dual mode link mechanism decides whether a message is forwarded immediately or not based on the following policy. The node of each directed link is considered primary or secondary. Primary links allow immediate sending of messages, while secondary links must first announce the availability of messages. Only if the receiving side needs the announced messages then the messages are send.

How it Works

A P2P Messaging system is a new middleware that supports the peer to peer communication. Here it focuses on the group communication based on the multi-ring topology. The Overlay network is first constructed based on the multiring topology. Each ring node is connected to two neighbor nodes in order to form a ring. When a node wants to broadcast messages to the other ring nodes, it sends the messages in both directions to its neighbors. Each node receiving messages from a neighbor forwards them to its other neighbor. Internally, arriving messages are put in first in first out (FIFO) message queues until a sender forwards the messages. In addition, the node keeps track of received messages by storing their unique ID. If a message arrives more than once, the node simply ignores it The ring topology allows establishing backup procedures easily. The proposed mechanism is based on backup links, which remain inactive until they are actually needed. Each node has two backup links to the nodes next to its neighbors. When the P2P Messaging System detects broken links to failed nodes, it removes them and activates the backup link. The activated backup link is converted to a regular link, and new backup links are established to restore the ring completely. Backup links are also used when a neighbor node is congested because it did not receive, process, or forward the data fast enough. These mechanisms increase robustness and overall throughput.

Implementation

The P2P Messaging System is implemented in Java and thus is platform independent. Further, because its network protocol is language independent, implementations in other programming languages and platforms are possible. Experiments, which directly compared the P2P Messaging System with JXTA, provided evidence for a superior performance, reliability, and scalability compared to JXTA's group communication facilities. Using the JXTA technology the communication between the peers are established and all peer services and monitoring are performed. The comparison with P2P Messaging System is done with message size and data rate with respect to the number of receivers joined in the peer.

III. COMPARISON WITH EXISTING SYSTEMS

JXTA is a slow non reliable technology that decrease the performance with increasing number of receivers.P2P Messaging System is fast and reliable middleware for peer to peer networks that is used for.

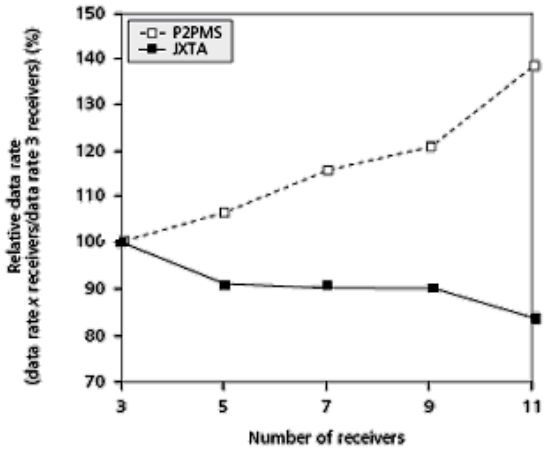

Figure 2. Data rate with increasing number of receivers

IV. CONCLUSION

This paper investigates the middleware design for peer to peer networks. Here peer to peer network is targeted because they lacked efficient group communication methods. A P2P Messaging System for peer to peer networks is designed and its performance is analyzed with the existing JXTA technology. The P2P Messaging System improves peer group communication by Collaboration with peer-to-peer network and by constructing an Overlay network for unicast configuration and provides stable performance with increasing number of receivers. JXTA still has to mature because the performances are not fully optimized.P2P Messaging was designed to provide high performance and better communication in peer to peer networks. Each peer group. The Multi-ring topology concepts that support Decentralized, Inner rings, Backup links, and Dual mode links provide better performance for communication.

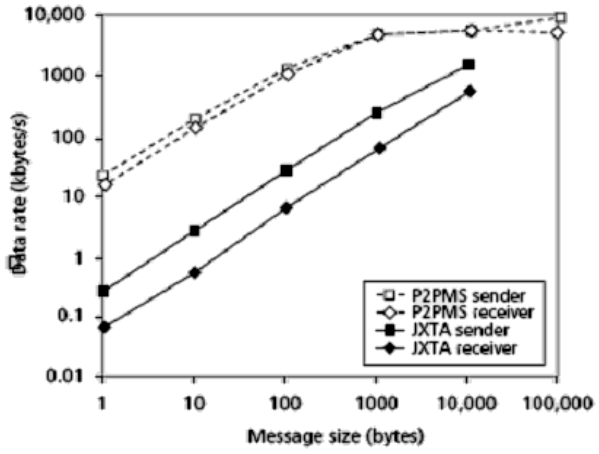

Figure 5. Data rate depending on message size

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