Computer Engineering and Intelligent Systems
ISSN 2222-1719 (Paper) ISSN 2222-2863 (Online)
Vol 3, No.7, 2012

Study of the Topology Mismatch Problem in Peer-to-Peer Networks

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ABSTRACT

The advantages of peer-to-peer (P2P) technology are innumerable when compared to other systems like Distributed Messaging System, Client-Server model, Cloud based systems. The vital advantages are not limited to high scalability and low cost. On the other hand the p2p system suffers from a bottle-neck problem caused by topology mismatch. Topology mismatch occurs in an unstructured peer-to-peer (P2P) network when the peers participating in the communication choose their neighbors in random fashion, such that the resultant P2P network mismatches its underlying physical network, resulting in a lengthy communication between the peers and redundant network traffics generated in the underlying network[1] However, most P2P system performance suffers from the mismatch between the overlays topology and the underlying physical network topology, causing a large volume of redundant traffic in the Internet slowing the performance. This paper surveys the P2P topology mismatch problems and the solutions adapted for different applications.

I. Introduction

There are plenty of research going on to address this issue and lot of other fields like neural networks[2],graph theory[3],artificial Intelligence are put in to use for finding and eliminating topology mismatch in P2P networks. There are still issues that cannot be solved thoroughly as each of the work has some specific drawback in solving the issue.P2P networks by default can be classified in to several types based upon certain attributes like 1)Pure P2P 2)Hybrid P2P.Based upon the attributes of peer administration ,P2P Networks is broadly classified into central directory based P2P system, e.g. Napster [4]; the decentralized unstructured P2P systems, e.g. Gnutella [5] and Kazza [6]; the decentralized structured P2P systems, e.g. Chord [7], CAN [8], Pastry [9], and the reinforced P2P systems such as Bamboo [10], Accordion [11], and PROP [12].Inspite of their significant potential, the available peer-to-peer networks lack efficient group communication. This article analyses the prospects and constraints of P2P networks and the topology mismatch problem ,and the solutions available to the problem. It also analyse the performance of each of the solution and finds the better of them [13]. The remaining part of the paper is organized as follows: Section 2 deals with P2P topology mismatch problem. Section 3 discusses the previous techniques to reduce topology mismatch problem and Section 4 gives the conclusion of this paper.

II. Peer-to-Peer Topology Mismatch problem

The peer-to-peer topology is fully decentralized one in which each network node is considered a peer, which has connection to a peers in an order. Simple peer-to-peer networks, just forwards messages to each and every peer. The modern P2P Networks depends upon several routing mechanisms for forwarding messages, inorder to prevent message flooding [10]. The advantage in making use of a peer-to-peer topology for our message transactions is that it doesn't involve central servers or routers. By the way, connections and workload are shared among the peers who form a greater advantage. It also has its own disadvantages like the latency is usually high, as messages have to traverse multiple peers. On the other hand the problem of the performance being degraded by slow peers on the route is also high. The bandwidth of each of the peer is consumed by traffic caused by other peers to some extent. The primary problem with the P2P networks is inefficient overlay topology mismatching that takes place very often resulting in unnecessary blind flooding[12] which has certain undesirable consequences which leads to innumerable problems like performance degrading, deadlock, slow system performance.The Topology mismatch between the P2P logical overlay network and physical underlying network is a common in almost all P2P networks. The Same message may traverse the same physical link multiple times causing traffic eventually resulting in poor performance. In this case, a query is flooded to multiple paths, but merges to the same peer. Thereby two neighboring peers may forward the same query message to each other and the same query message may traverse the same logical link twice. This results in overall Beefed P2P traffic and congestion.

In Fig 1, a query is broadcast and rebroadcast until a certain criterion is satisfied. If a peer receiving the query can provide the requested object, a response message will be sent back to the source peer along the reverse path. A query message will be dropped if the query message has visited the peer before. Solid lines denote overlay connections among logical P2P neighbors; a solid arrow represents a delivery of the query message along one logical connection. A query is relayed by many peers, which incurs a lot of unnecessary traffic, for example, after node S sends the query to L and M since none of L or M knows the other one will receive the same query from S, they will forward the query to each other, node M receives query message for 4 times from S,L,P,Q. After the vitality of Peer-to-Peer (P2P) file sharing applications was felt, several users started using their personnel computer for more than browsing .With the development of the networks, the P2P model is quickly emerging as a significant computing paradigm of the future Internet. There are currently several P2P systems in operation and many more are under development. Nevertheless, the mechanism for a peer to randomly choose logical neighbors, without any knowledge about the physical topology, causes a serious topology mismatch between the P2P overlay networks and the physical networks.

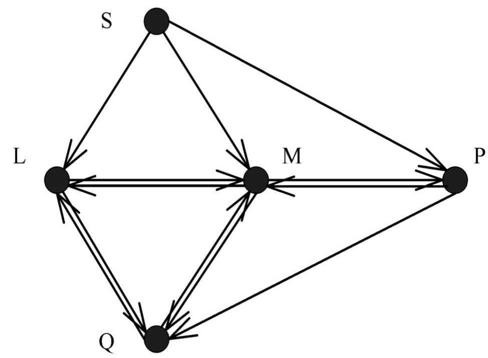

Figure 1: unnecessary traffic by flooding

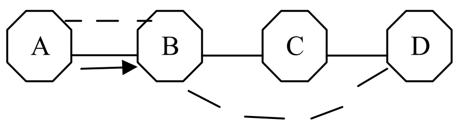

Figure 2(a) example of p2p overlay network

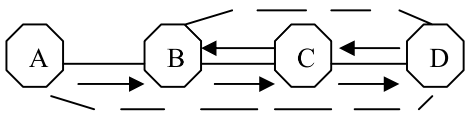

Figure 2(b) example of p2p overlay network

In fig 2(a) A,B and D are three participating peers and physical topology nodes A,B,C and D. Solid lines denotes physical connections and dashed lines denote overlay connections. Consider the case of a message delivery from peer A to peer B. In fig 2(a) A and B are both P2P neighbors and physical neighbors thus only one communication is involved. Similarly in fig 2(b) since A and B are not P2P neighbors, A has to send message to D before forwarding to B. This involves 5 communications. Clearly such a mapping creates much unnecessary traffic and lengthens the query response time. This phenomenon is called topology mismatch problem.

The lack of synchronization between physical topologies and logical overlays is a major factor that increases the overall response time, which is determined by the product of the routing hops and the logical link latency. Mismatch problem also causes a large volume of redundant traffic in inter- domain between the every Internet Service Provider. This forms the reason for ISP's to prohibit P2P applications [14, 15, 16]. Primary literature survey states that at most more than 75% of the P2P systems suffers topology mismatch problem [16]. The issue of mismatch in P2P systems has been the focus of intensive research in several paper [15,16,19] and the solution for the same is also provide in[20,21]. The research carried out on the P2P networks can be classified in to several categories based upon the type of contribution to P2P working. Hereby we discuss the several research and their outcomes in terms of improving P2P networks.

In order to follow a better approach and to nullify the effect of topology mismatch several innovative algorithms and approaches are made and tested to use. Earlier in the year 2003 studies were done to address the mismatch problem based on peer coordinate systems, demonstrating the possibility of calculating synthetic coordinates to predict Internet latencies. The plot relied on a small number of nodes called master node, which are predefined and other nodes choose coordinates based on RTT measurements to the landmarks. The Master node has to be chosen with care to get greater results [17].

In another algorithm, Vivaldi [18] is a simple, light-weight algorithm that assigns synthetic coordinates to hosts such that the distance between the coordinates of two hosts accurately predicts the communication latency between the hosts. Although Vivaldi ensures nodes always decrease the prediction error and has no use for the choice of landmarks, it is so complex that hard to deploy in Internet. In addition, Vivaldi’s convergence of coordinate system is a slow process. Another study approach is a hierarchical location-based node IDs in P2P systems proposed by [19]. Physical locations and network distances are effectively embedded in the node IDs, and thereby improving routing locality. However, what is the influence on load balance is an important question concerning embedding location prefixes in node IDs.

The another innovative clustering algorithm such as Coral [20] takes a very different approach letting the peer discovering the router IP cluster by randomly trace routing and then choosing the first five routers as the close cluster and joined into the cluster. But this scheme is coarse-grained and has difficulty to distinguish relatively close nodes, thereby minimizing the topology mismatch.

III. Previous work on Topology Mismatch

In [3] a novel technique is proposed and named DNSR (Domain Name Suffix-based Routing)evaluation technique to route query messages in Overlay Networks, based on the ”domain closeness” of the node sending the message. Simulation results of the experiment shows when performed over PeerWare on Gnutella a better performance of P2P[3].The application layer working Peer-to-Peer (P2P) networks facilitate users in performing distributed functions such as keyword searches over the data of other users. The primary problem in such networks is that the connection among peers are arbitrary, leading in that way to a topology structure which doesn’t match the underlying physical topology. This phenomenon leads to excessive network resource consumption in Wide Area Networks as well as degraded user experience because of the incurred network delays[3].

In unstructured peer-to-peer (P2P) systems, the occurrence of topology mismatch between the p2p logical overlay network and the physical layer causes traffic issues and the main reason for the same is a peer randomly joining and leaving a P2P network[Efficient P2P network overlay construction]. There have been studies and experiments on the issue of nullifying the topology mismatch in peer-to-peer (P2P) systems and there by significantly improving the response time and reduce traffic.The one possibility is by introducing distributed algorithms to optimize the overlay. Several ways to solve over-lay topology mismatch problems in P2P systems are discussed in the below mentioned papers [10,11,12,13,14]. In [25] authors have taken in to account Adaptive Connection Establishment (ACE) where every single peer involved in a network constructs an overlay multicast tree like structure between themselves based upon the source node and the peers within a particular distance from the source peer, Likely it optimizes the neighbour connections that are not on the tree structure, while retaining the search scope. The research also has a proven simulation result showing exponential improvement in P2P systems.

In [21], the convergence speed is taken in to account in ACE and a location-aware topology matching (LTM) scheme is proposed. Here in the process, peers make use of a recording detector, for recording relative delay information essential as an attribute to reduce topology mismatch. The obtained delay information, helps the receiver to detect and delete inefficient logical links based upon its redundancy, The simulation results obtained based on the same algorithm has shown a positive reduction of response time up to 80%.

In [22] the problem of traffic overhead is solved, a scalable bipartite overlay (SBO) is proposed. The SBO employs an efficient strategy for distributing optimization tasks in peers with different colors and each color denotes the time to contact a neighbor. Newly joining peers are assigned a separate color for identification. A white peer that is not on forwarding paths of a red peer then tries to find a more efficient red peer to replace this red neighbor. The evaluation of the results have shown good outcome. [23] Deals with a self-organizing peer-to-peer system built upon an application level overlay, whose topology is independent of underlying physical network. A well-routed message path in such systems may result in a long delay and excessive traffic due to the mismatch between logical and physical networks. The peers in a P2P system arrange themselves in a virtual network called the overlay network. The overlay network sits above the underlying physical network and is used to search for resources and peers, and to route messages between peers. The topology of the overlay network is the graph whose vertices are the peers and whose edges are the connections between the peers. The choice of topology affects application performance and the correct choice depends on the application [24].

Coming to the unstructured systems, such as Gnutella [3] and KaZaA [5], place documents and nodes randomly, without correlation with the network topology. Unstructured systems exhibit ease in topology maintenance but face two main problems that seriously degrade their performance [22] [23].

1) Topology mismatch between the overlay network and its underlying network,
2) Inefficient flooding-based search for desired content.

This paper focuses on the possible performance improvements of decentralized unstructured P2P systems. We deal with the first problem by initializing overlay links according to the underlay proximity when nodes bootstrap and the flooding-based search is based on it. For the second problem, we intend to forward the query to the most relevant nodes by introducing a table called file table appended to each file. Its entries point to some of the nodes that also have this file, thus forming a SIG (special interest group) corresponding to this file. In this way, a semantic overlay network called CON (content overlay network) is embedded into the existing overlay network. Now two kinds of complementary search mechanisms are available: one is based on SIG, the other on flooding. While interesting research are there in solving overlay topology matching problems do not enhance the performance metrics due to the communication delay between the peers ,this paper presents a innovative topology matching algorithm with good performance qualities. In the proposal, the method is that, each participating node creates and manages a constant number of overlay connections to other peers in a distributed fashion. The performance analysis shows that the expected overlay communication delay between any two nodes in our P2P network is a constant and in addition to it, any joining node has the exponential broadcasting scope in expectation an, another advantage is, a participating node takes a polylogarithmic overhead to exploit the physical network locality and maintain its flooding scope. Extensive simulation of the algorithm shows that the proposal outperforms two recent solutions like THANCS and mOverlay, with respect to overlay communication latency and broadcasting scope [26].

In [1] an unstructured peer-to-peer (P2P) network like Gnutella was taken in to account .here the participating peers choose their neighbours randomly in a fashion the resultant P2P network mismatches its underlying physical network, increasing the communication time between the peers and thereby increasing the traffic. to solve this ,in order to solve this problem ,the paper has proposed a novel topology matching algorithm based on the Metropolis-Hastings method. The proposal considers real time analytical readings and has an optimal design. Specifically, the proposal constructs an unstructured P2P network in which a broadcast message, originated by any node r, reaches any other node t by taking approximately the only physical end-to-end delay between r and t.

In [27] Topology constructions of the existing systems are designed based upon certain factors like usability and validity and other factors like underlying IP network topology are not taken in to account causing several problems like delay of routed messages and poor scalability. This paper provides the solution for the same problem with the help of fuzzy logic. Here they have presented a topology formation algorithm for partially decentralized overlay. The algorithm makes use of central landmarks as a point of reference to gain and analyze the round-trip time between joining node and landmarks. This algorithm thereby improves topology-matching degree to a good extent when compared to random method.

In [28], This paper deals with graph based performance techniques to understand the topology mismatch problem and it comes with a better solution for the same .proposes the development and application of random graphs-based performance evaluation techniques to understand design trade-offs for hierarchical unstructured peer-to-peer networks. In particular, the connections between lower and higher level peers (that are known as leaves and ultra-peers in the Gnutella jargon) are modeled as a bipartite random graph while the overlay network used by ultra-peers to forward queries is modeled as a generalized random graph. Both the random graph models consider peers of either level as partitioned into classes; this feature is included in the model description to consider the mismatch between the logical topology of the application and the physical deployment of peers throughout the Internet. To assign realistic values to the input model parameters and to validate the model predictions we obtained snapshots of the Gnutella application topology at both levels and conducted simulation experiments on these snapshots. The paper highlights a few exploitations of the modeling technique with a particular focus on the evaluation of the impact of locality awareness on user and network performance measures. [29] almost all peer-sampling algorithms suffer from many topology oriented problems as they require specially constructed topologies like gossip peer tables and are hard to parameterize correctly and efficiently and they do not offer precise statistical guarantee. This work proposes two distributed algorithms that addresses problem that helps to assign the link transition probabilities of a peer-to-peer network and another to estimate the largest magnitude eigen values of a peer-to-peer network.

In [32] then have considered an existing P2P file sharing system and tried to make in free from topology mismatch. Optimization is done with the introduction of a new scenario in which a certain bandwidth is allocated to each of the peer and the level of downloading capacity is set to a value for each of the peer based on the peer's currency, which when high gives greater bandwidth for the peer and the peers can choose the service peers by demand based on the file price and the download speed. This way they are reducing the mismatch and low efficiency problem. The paper has got experimental proof for the same and has proved that the currency-based system works. The discussions and solutions in [33] for solving topology mismatch problem are unique and proven with experimental simulations. Almost all topology constructions on any of the existing overlay are based on factors like usability and validity and only very little consideration is given to the underlying IP network topology which forms the main reason for the mismatch of topologies between overlay and IP network. This is not just the problem and there are chain of problems resulting from the topology mismatch like delay in routing message, low resource utilization and bad scalability.

Resolutions can be made to enhance the routing efficiency of existing centralized or decentralized overlay networks, but the drawbacks are not limited and extent to like overlay protocols dependent and high maintenance overhead problem. The paper deals with solving the problem with a topology construction algorithm based on fuzzy clustering and works for partially decentralized overlay. The working of the algorithm uses centralized landmarks for reference to calculate rtt (round-trip time) values between joining node and landmarks. The values got by the means are clustered to form a decision. Experimental Simulations show that other schemes cannot improve topology-matching degree like this does. The results are compared with random method.

The Gnutella virtual network topology [34] also has the topology mismatch problem with the underlying Internet topology, leading to non efficient use of the physical networking infrastructure. The paper finds out way to propose changes to the Gnutella protocol and implementations that has brought upon significant performance and scalability improvements. The paper also brings out measurement and analysis techniques to find how robust the P2P network is. The paper analysis that Gnutella connectivity of node is based on multi-modal distribution by which power law component and quasi-constant distribution component are combined. This mode of operation increases the reliability, as experimental results without the approach shows reduced efficiency as well as free from several attacks. The paper gives two ways to improve the design of peer-to-peer networks, to avoid topology mismatch, one approach states that efficient P2P designs should make use of meticulous distributions of inquiry values and locality of user interests similar to that happens in distribution of HTTP requests in the Internet. When nodes in a dynamic P2P network rely on by user interest, a query-caching scheme can bring larger performance improvements.

The second way of improvement discussed is replacement of query flooding mechanism with smarter routing and/or group communication mechanisms. A way to preserve the dynamic, adaptive character of the Gnutella network and still decrease resource (network bandwidth) consumption is to use dissemination schemes (e.g., based on epidemic protocols) mixed with random query forwarding. We have collected a large amount of data on the environment in which Gnutella operates, and plan to use this data in simulation studies of protocol alternatives. The efficiency and robustness of the P2P network can be guaranteed by making it topology matching, for the same the paper [34] have prescribed a feasible and testified solution. It mentions the creation of a super-node based Overlay and the design of overlay is based on Information Exchange named SOBIE. The SOBIE differs for all the other types of P@P overlay like structured, unstructured, meshed and tree-like P2P overlay. The working of SOPHIE to minimize topology-mismatch in order to improve the efficiency is by selecting the super-nodes by considering the aggregation of delay and distance and also by reducing the time of information exchange between the two peers. The Exchange of information is done more frequently in a useful manner. One more mechanism addressed here is to set a counter mechanism to find and stop free-riders using the P2P networks [31]. To the context of P2P, a free rider is a peer only using then other peers, but not contributing any service to other peers, which is unacceptable in a colonial format of Peers. This will lead to a similar effect as of topology mismatch. With SOBIE[30] ,several experiments have been done and the results shows that the p2p model can achieve high efficiency and robustness by such different factors like the query success rate, the average query hops, the total number of query messages, the coverage rate and system connectivity which are all put into use by several means.

The applications of P2P systems depends completely on the topology and there are many different P2P topological overlay like structured and Unstructured [35]. Structured P2P topologies depends upon Distributed Hash tables for storing and retrieving a data item based on an exact key resulting in high scalability. The same scenario doesn't give good result if the search key is unique or similar [35]. In the case of a decentralized structured network, the same process happens with the help of key space lacking adaptability and fault tolerance [36], almost all DHT-like structured P2P overlays do not consider the heterogeneity and the mismatching between physical and logical locations resulting in more management overheads and fragile topology.

Unstructured P2P networks like Gnutella 0.4[37] adapts their behavior dynamically according to the individual users requirements, resulting matching of topologies. But, if the volume of query traffic increases the scalability and efficiency of this approach diminishes.

In [38] a proposal of a framework specifically for analyzing peer-to-peer content distribution technologies is made and it analyses the nonfunctional individuality like security, scalability, performance, fairness, and resource management. The framework also examines the way in which these characteristics are reflected in and affected by the architectural design decisions adopted by current peer-to-peer systems. There are several literatures dealing the topology mismatch problem by generous solutions and algorithms. In paper [39] comparison where made on the overlays of several structured and unstructured P2P networks. The paper considers various attributes for analyzing the overlay like Decentralization, Architecture, Lookup Protocol, System Parameters, Routing Performance, Routing State, Peers Join and Leave, Security, Reliability and Fault Resiliency in order to design a perfect topology free from mismatch.

IV. Conclusion

The paper discusses the solution provided by other P2P networks like CAN[40-44] and unstructured P2P networks like Freenet [45] ,Gnutella [46-48] ,FastTrack [49], P2P BitTorrent [50] and Overnet/eDonkey [51-52]. Comparing the architectures of CAN, Chord, Tapestry, Pastry and Kademlia, it has been observed that each of them follows a different format of architecture and the each of it is suitable for a certain kind of application. In terms of Lookup Protocol the viceroy P2P is better than the other according to the simulation reports. Routing performance and routing states are good in CAN, than other P2P's. Overall security of the P2P's are not sufficient to avoid man-in the-middle and Trojan attacks.

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