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Cost-Effective Resource Allocation of Overlay Routing Relay Nodes

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Abstract: ***Internet is the most popularly used application all over the world. The main aim of the Internet is to provide end to end services and a variety of information and communication facilities with high availability and faster response. Variety of work is done and continuously in progress to detect and reduce factors that affect Internet availability. The link and router failures along with some other factors mainly affect the Internet performance. One way to improve Internet behavior is to spread intelligent routers all over network those manage traffic through other intermediaries. Such intelligent nodes called as relay nodes or overlay nodes, and path travel through them called as overlay path whereas the resultant system is called overlay network. These nodes operate dynamically and provide an extra functionality to existing infrastructure. Different overlay networks offering different services may place on same substrate at same time and substrate must allocate resources fairly to them. The Overlay Routing Resource Allocation (ORRA) technique provides a general framework structure that can be used in variety of applications and offer low maintenance as compared to other overlay systems like Resilient Overlay Network (RON), Detour etc.***

Keywords: overlay, routing, relay

1. Introduction

Millions of users using Internet and thousands of new users added every day. Varieties of different networks having different architectures are connected to provide the Internet services to millions of the users. All the networks composed of independently operating autonomous systems, each of which is maintained and configured by different administrators. This heterogeneous nature and scalability of Internet shows there is a need of improving robustness, adaptability, performance and availability. The Internet faces variety of problems, such as software failures, hardware failures, performance failures, congestion and slow speed etc. These all inefficiencies of Internet are studied from many years and designers trying to improve the reliability of Internet with better performance. Multiple paths are present between source and destination. The different routing policies select one path among them for data transmission. But sometimes path selected by routing policy is longer. The overlay selects the shortest path among multiple data paths for fast transmission. Overlay network selects different nodes from the existing infrastructure those are used as intermediaries for data transfer. These intermediate nodes are maintained and configured for better performance.

The overlay network not only improves the performance but also adds an extra functionality to existing network without changing its infrastructure. There is no need of standardization and global deployment of new functionality. It adds a virtual layer of functionality. The intermediate nodes chosen are called as relay nodes are configured to provide this functionality. Different overlay networks offering different types of services present previously. Those are application specific in nature and provide specific functionality to the network. Overlay Transmission Control Protocol (oTCP) improves the TCP performance by splitting the TCP connection with higher Round Trip Time (RTT) into multiple TCP connections with lower RTT. The reliability of network is improved by the RON. In RON the different RON nodes are connected in mesh topology to provide higher fault tolerance. Detour use the tunneling concept for providing the robustness. It hides details by encapsulating the packet in to other packet and forward using alternate path on the Internet. To provide the faster response the Global Internet Service Provider (G-ISP) uses an extra ISP to give response to the customers.

To add an extra functionality and improve performance we have to select overlay nodes from present infrastructure nodes. This deployment and maintenance of such overlay nodes comes with non-negligible cost in terms of hardware, software, operating and human interventions etc. Thus it is important to study the cost against the improved performance and try to find a solution with minimum cost. All previously studied overlay networks not considered the cost associated with this deployment. Different overlay networks providing different services can be placed on the same substrate at the same time. Those all compute for the resources. The substrate must allocate resources fairly. Regardless of specific application in mind ORRA tries to get a minimum number of infrastructure nodes that can be needed to add in order to maintain a specific property in the overlay routing. It uses the shortest path routing over BGP- based routing and find minimum number of relay nodes those can provide shortest paths between group of autonomous systems. It uses a greedy approach and suggests a small number of relay nodes that can significantly reduce latency in BGP routing and improves the performance.

2. Related Work

Wide variety of applications uses TCP for data transmission over 3 decades. In TCP reducing RTT between connection end points increases the window size faster resulting in increased throughput. H. Pucha *et al.* proposed Overlay TCP (oTCP) as an application-level protocol which acts as an extension to TCP in [2]. It splits an end-to-end TCP connection with high RTT into pipelined sub-connections with small RTTs using in-between nodes to get enhancing throughput. oTCP also reduce failures and find out paths that are superior to the direct path. oTCP is a feasible architecture for throughput demanding applications; as it build on top of unmodified TCP so that the TCP behavior is remain unchanged and it terminates the overlay connection in transport layer rather than network layer.

D. Andersen *et al.* proposed more reliable application layer overlay network called as RON [3]. Where RON nodes come from variety of routing domains and assist each other for fast data transmission. In less than twenty seconds RON detect and recover from path outages. RON enhances loss rate, latency, or throughput by data transfer using alternate paths in case of fault detection and recovery. RON nodes use aggressive probing and monitoring of paths to communicate each other and detect the problems in network. They exchange path quality information to select best path for data transfer. If the underlying Internet path is best then that is used for data transfer otherwise RON nodes come in action and data forwarding is done through RON nodes. RON nodes are connected in a complete graph to provide fast recovery from failures. The cost of building RON is higher. RON increases the reliability and availability of the application by forwarding data by recovering failures.

A routing system is responsible for selecting links for data transfer but it spread traffic unequally; where some links are idle and some are over utilized. To improve the reliability and performance one can use such idle links. S. Savage *et al.* proposed a framework called as detour, which act as a new virtual network which builds on top of existing Internet in [4]. Detour consists of a set of physically distributed router nodes interconnected using a virtual link called tunnel. Each packet goes inside a tunnel is encapsulated into a new IP packet and forwarded through the Internet until it reaches the tunnel's exit point. Detour nodes are edge devices and exchange path information. They use alternate paths instead of dedicated links.

A Global-ISP (G-ISP) is proposed by R. Cohen *et al.* in [5], can be viewed as an additional ISP that provides transit services to its customers over an overlay network. It provides an extension to the standard BGP [18] protocol. It is designed to solve, or at least reduce, problems of inter-domain routing protocol, such as slow convergence, and lack of QoS and multicast support. It uses IP in IP tunneling concept to connect with the customer and provides inter-AS multicast support.

3. Proposed System

The main focus of the proposed approach is to provide a generalized frame work structure that can be used in variety of overlay applications. Also need to consider the cost associated with this deployment and tries to minimize the same. The ORRA approach provides such structure that fulfills requirements.

A graph G = (V, E) describes a network topology where the V indicates the topology nodes simulating routing nodes and E indicates a set of links simulating communication links between these nodes. Let P_u be the set of routing paths derived from underlying routing policy, and P_o is the set of routing paths derived from overlay routing scheme. All the direct paths with single hop are in P_u. P_o defines as the set of shortest paths with respect to a weight function $W: E \rightarrow R$ over the vertices. This indicates the processing cost or preference how good it is. When a source – destination pair (s, t) is given then the overlay path between s, t $\in$V, denoted by $P_o^{s,t}$ is the set of overlay paths between s and t, where $P_o^{s,t} \subseteq P_o$, and $\forall p \in P_o^{s,t}$ the end points of path p are s and t. While link are selected by considering minimum link weights indicating available band width. Let's consider the U as the set of Relay nodes, that used to perform overlay routing from sources to destinations such that packets can be routed from one relay node to another using underlay paths. As $U \subseteq V$ i.e. U covers (s,t) if $\exists p \in P_o^{s,t}$ such that p is a concatenation of one or more underlying paths, and the endpoints of each one of these underlay paths are in $U \cup \{s\} \cup \{t\}$ as proposed by Rami Cohen *et al*. The focus is on finding set U with minimum number of relay nodes those can be used for data transmission in case of any failure. Each source destination pair must be encountered by these overlay nodes with shortest path. The Enhanced Overlay Routing Resource Allocation (eh-*ORRA*) problem is defined as follows:

Definition:- Given a graph G=(V,E) and Q is a set of all source destination pairs, select a set of overlay nodes $U \subseteq V$ that covers Q and act as relay and provide shortest path for data transmission.

A. System Architecture

Figure 1 shows the system architecture. The most popular inter-domain routing protocol is BGP. The BGP exchanges the network reachability information with other BGP systems [6]. Depending on this path metrics the shortest paths can be selected for transmission. Some nodes in the network can be maintained to improve the performance. These nodes are called as relay nodes or overlay nodes. Those act as routers and forward the packets to its destination. When the sender starts the data transmission the overlay routers select the best path depending on various majors. The data transfer done between source to overlay router and overlay router to the destination. All end to end semantics are maintained and data is forwarded to corresponding destination.

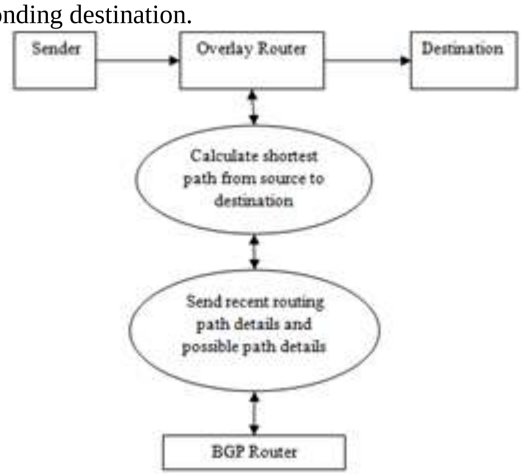

Figure 1: System Architecture

B. Algorithm

The overlay routing resource allocation (ORRA) algorithm is used to find the possible relay nodes. This is greedy method. Result is near optimal solution. This is a recursive algorithm for NP hard ORRA problem.

Terms:
$Q = \{(s_1, t_1), (s_2, t_2), \ldots, (s_n, t_n)\}$ – all source destination pairs
$P_o^{s,t}$ = set of overlay paths between s and t

Inputs: G (V, E) network topology, W – Weight function W: $V \rightarrow R$, P_u – Set of underlay paths, P_o – set of overlay paths, U – Set of relay nodes.
Steps:
ORRA (G = (V, E), W, P_u, P_o, U)
Step 1: $\forall v \in (V\text{-}U)$, if w(v) = 0 then $U \leftarrow \{v\}$
Step 2: If U covers Q then return U
Step 3: Find $(s, t) \in Q$ not covered by U
Step 4: Find $\forall v$ present on $P_o^{s,t}$ and $v \notin U$ then $V' \leftarrow \{v\}$
Step 5: set x = $\{\min w(v) \mid v \in V'\}$
Step 6: set w1(v) = $\begin{cases} x, & v \in V' \\ 0, & otherwise \end{cases}$
Step 7: $\forall v$ set w2(v) = w(v) – w1(v)
Step 8: ORRA (G, w2, P_u, P_o, U) go to step 1
Step 9: $\forall v$ if U-{v} covers Q then U=U-{v}
Step 10: return U
Output: The set of relay nodes U is the output of algorithm.

C. Functional Diagram

Figure 2 shows the functions performed while selecting a set of relay nodes using ORRA algorithm. The algorithm must know details of network topology given as input. When network information is known to all nodes, the TCP connections are established between nodes. BGP decides routing policy for path selection. This path information exchanged with different BGP routers. BGP can apply different ratings to different paths depending on various factors such as delay, bandwidth and congestion etc. When the nodes want to forward data on network, first the source destination pair is selected, depending on the path rating decision of whether to use direct path or overlay path is done. If overlay path is taken then relay nodes on that path are selected to maintain data transmission. Selected overlay nodes then performs the data transmission.

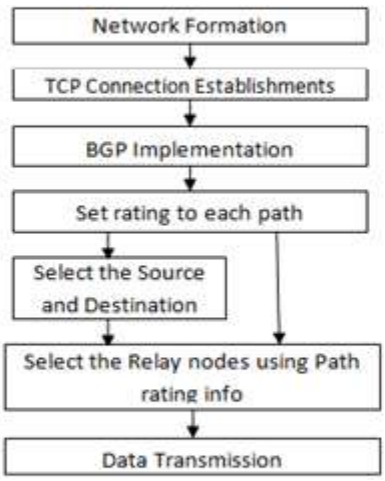

Figure 2: Functional diagram for ORRA algorithm

4. Performance Analysis

This work proposed a novel approach based on link and node weights for resource allocation for overlay networks. The evaluation is done between proposed Link-Node weight based ORRA-LN approach and Node weight based ORRA-N approach. ORRA-N approach uses only node weight to allocate resources for data transmission. Whereas the ORRA-LN approach uses the node weight as well as the link weight to allocate resources for data transmission. The cost of routing is evaluated using two key performance metrics such as throughput and delay.

Performance Metrics for Delay:

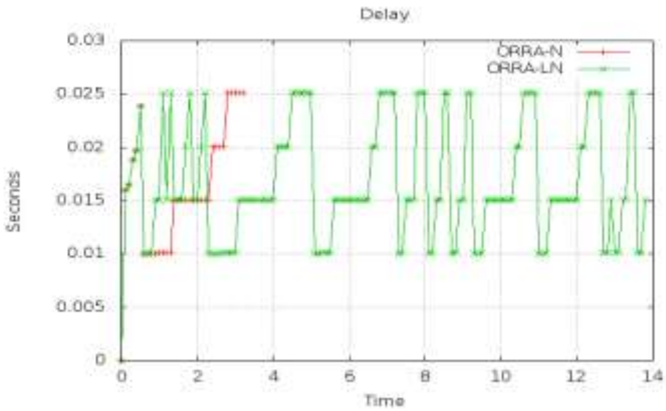

Figure 3: Performance Analysis for Delay

Figure3 shows the instance delay computed for a test case simulated using both ORRA-N and ORRA-NL methods. There is no much reduction in delay. The delay graph shows the high variations in response times that impact the proposed system. This happens because of transit congestion or timeouts, which results poor performance of the provider path to the destination. The throughput observation shows the actual improvement.

Performance Metrics for Throughput:

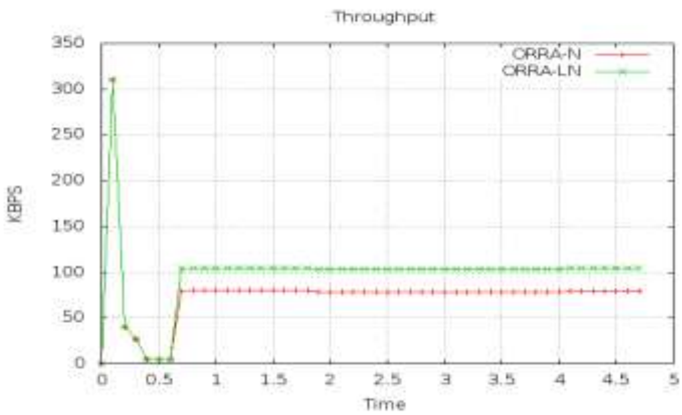

Figure 4: Performance Analysis for Throughput

The throughput graph shows that, the throughput suddenly increases and then goes on decreasing slowly. After a threshold values it goes constant. As the throughput is increases, the ORRA-LN technique gives the better results than the ORRA-N technique. But as the network complexity is increased both delay as well as throughput results get affected due to more number of resources involved in overlay network and results in decrease in average throughput. As the proposed approach shows the significant increase in throughput the communication cost reduced. That means it delivers the better performance in minimum cost involvement.

5. Conclusion

All previous overlay systems do not consider the cost associated with deployment of overlay nodes and are application specific in nature. But proposed ORRA technique considers the deployment cost and tries to minimize the same; it also provide a generalized frame work structure for variety of applications. It gives a set of relay nodes those can provide shortest path considering node weights. If we apply the link weights too the resulting path is more cost effective than path considering only node weights.

6. Future Directions

It would be interesting to study the performance of proposed approach for other routing scenarios and to study issues related to actual implementation of the scheme. It also interesting, to apply the proposed system for networks where all attributes like RTT, bandwidth etc. is known.

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