АВТОМАТИЗАЦІЯ ТА ІНТЕЛЕКТУАЛІЗАЦІЯ ПРИЛАДОБУДУВАННЯ

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SUBSTANTIATION OF THE LOCALITY METRIC APPROACH IN THE MODERN PEER-TO-PEER NETWORKS

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This paper is concerned with further improvement of CARMA network model by considering multifaceted asset relationships, which results in the increase of detail between adjacent locality classes. Also the more structured substantiation and generalization for the necessity of locality metric in P2P networks is provided, along with outlining of the most common drawbacks present in an already developed methods and tools and proposed solution components to address these drawbacks. An additional experimental runs concerning the correlation between traceroute and CARMA metric were done to detect possible daily variation of the swarm distribution.

Keywords: *internet, distributed networks, peer-to-peer networks, locality, clustering.*

Introduction

The information technologies possess greater influence on our everyday life and activities. They are reaching such a level of integration and mobility within our life that it could be compared to the importance of electric power. As of today, both domains of technology are so embeddedin the very survival of mankind that virtually no man-made activity is done without either one.

The modern Internet indicates traffic patternsindicative of the overwhelming presence of one single class of internetworking exchange, called «peer-to-peer» networking, or simply P2P. As of today, P2P is the most dominant traffic class in every major backbone network.

Today, the usage of P2P networks and scale, diversity and applicability had widened significantly, and the application scope of P2P systems has been notably extended. Being previously considered exclusively as a means for file sharing or instant messaging, today's P2P networks serve as a basic infrastructure for a wide range of innovative application scenarios such as VoIP, multimedia on-demand, software delivery, massive multiuser environments or online games, and even text messaging—generally speaking, almost all branches where the traditional client-server architectures are still dominating but steadily losing their grounds.

The core concept of P2P system was to reduce load on centralized systems, facilitatingserving capabilities of the very same network nodes of clients instead. Up until recently, the intrinsic asymmetry of end-user broadband data links has caused ISPs to increase maintenance and upgrade cost of the «last mile» hardware in order to keep quality of service steady.

Mainly because of this, researches in the area of P2P systems are aiming to optimize P2P traffic interaction patterns and consider the inherently clustered nature of the Internet as a potential leverage mechanism. The general idea discussed in the previous works is to maximize network throughput inside the particular network domain while minimizing the traffic usage between such domains.

In this paper we have two major goals: a) to improve upon the previously used CARMA (see below) model by implementing multifaceted asset relationship search and b) to substantiate and generalize the necessity for locality metric in P2P networks addressing frequent criticisms from specialists in this area claiming that CARMA-like mechanisms are of no significant advantage over competitors.

Previous work

In our previous works [1, 2, 3, 4] we havedevised a locally computed approach for topological distance estimation that does not rely on third-party non-guaranteed external infrastructures or unreliable active traffic probing and considered its usage in P2P networks. This approach was previously named «CARMA» which stands for **C**ombined **A**ffinity Reconnaissance**M**etric **A**rchitecture.

As described in [3], CARMA works by initially preloading structural information from publicly accessible services called Regional Internet Registries (RIRs) and converting it into an internal graph-like data structure. Once loaded, CARMA builds a model to approximate the Internet topology with some simplifications, resulting in 4 common structural layers (CSL) as follows: a) IPv4 ranges are divided into b) subranges but at the same time they also belong to c) Autonomous Systems (ASes), which are joined into sets called d) AS-SETs or ASSETs.

From these basic entities, CARMA is then able to define and determine the relative topological locality of two arbitrary nodes by sequentially find the lowest CSL.

As an estimation result, CARMA produce flavor index ranging from 0 to 7 according to the lowest found CSL, namely: “Subrange”, ”Range”, “AS”, “ASSET”, “ASSET-Link”,“Backbone”, “Country” and “Distant”. The latter is returned when all tests for the CSLs have failed to produce one.

Substantiation of the locality metric

All existing approaches concerning network locality in the sense of topological distance presentation could be grouped into four distinct classes. These are:

1. Utilizing standard transit tracing and latency metrics as is done in the Paris Traceroute approach [5];
2. Developing the interface layers between P2P network and standard Internet routing infrastructure such as BGP (Border Gateway Protocol); this is done in PlanetLabandASInfo [6] approaches as well as partially inRouteViewsproject.
3. Building dedicated supervisory network that accumulates information concerning peer relations from its nodes observation points [7].
4. Various modeling frameworks as well as Internet mapping projects.

Every one of the approaches mentioned has one of four disadvantages that it may share with the other three. These disadvantages are shown in the Fig.1 as the topmost boxes.

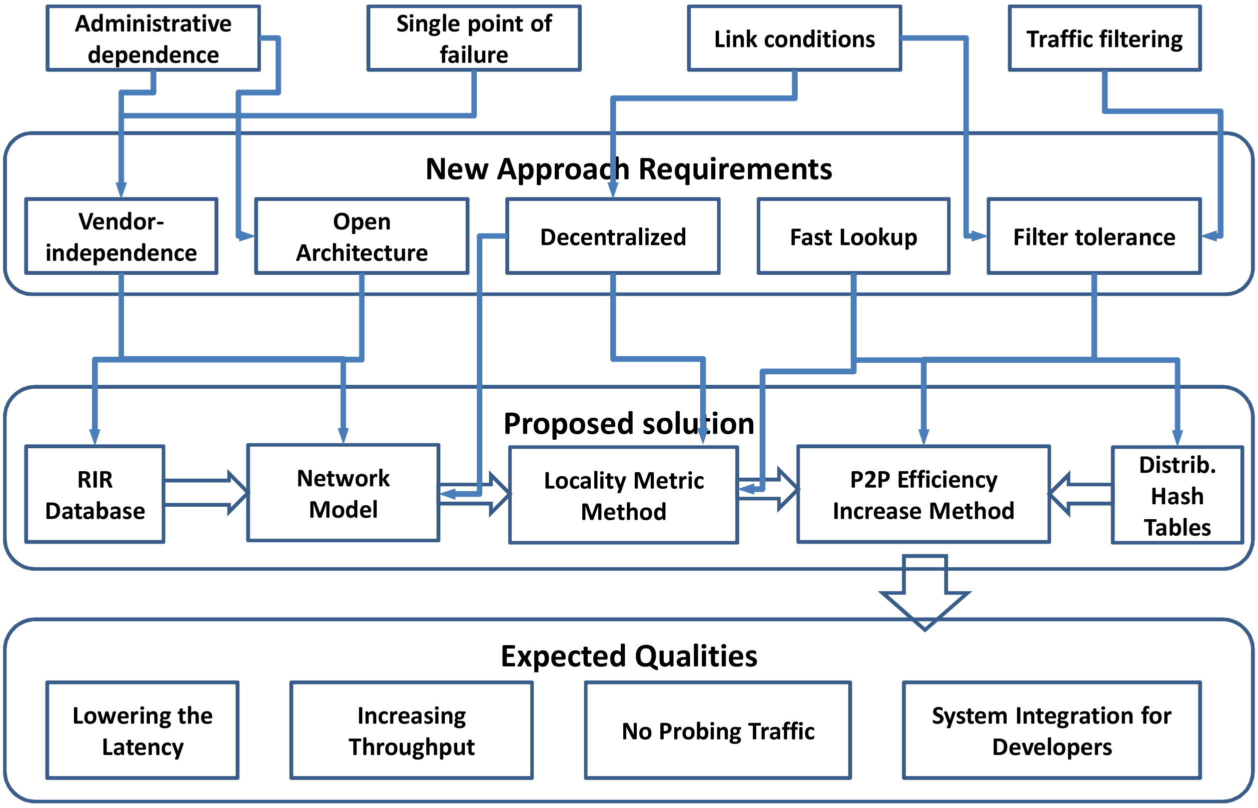


Figure.1. Common disadvantages of the existing approaches; new approach requirements; proposed solution and expected qualities – all pertaining to the locality metric concept in general.

The administrative dependence in this context denote the situation whereby proper functioning of the locality estimation system is dependent upon memberships, fees, management and political issues, etc.

The single point of failure, as in other cases, indicates that the locality calculation for the whole network is being done by a single system, failure of which prevents the calculation of metric network-wide.

Link conditions do affect locality estimation systems that employ active probing, such as aforementioned transit trace-derived methods. In particular, a certain traffic jam on any of the transit nodes may invalidate the locality metric result for the whole network subnet completely.

Traffic filtering may arise whereby the participating network employs various shaping and filtering rules that prevent certain classes of traffic or protocols from being transmitted. Usually this is observed in the subnets connected to upstream networks using translation scheme such as NAT (Network Address Translation) or when ICMP (Internet Control Message Protocol) is filtered out.

To mitigate the iterated issues we have developed the requirements that a new approach to locality estimation should meet. They are:

1. Vendor-independence: the source of information for building the network model should be either in the public domain;
2. Open architecture: there should be an open standard or, better, a common framework for implementing interoperable locality metric estimation tools and methods;
3. Decentralization: naturally avoiding single point of failure would mean that, under ideal circumstances, every participating node should be able to estimate at least its own locality against any other node in the swarm with no help from other nodes at the time of locality estimation;
4. Fast Lookup means that the estimation should take a time less than the connection to the node in question remains required or scheduled;
5. Filter Tolerance means that locality estimation should not be affected by external link conditions, and, ideally, be done by the module that does not require connection to the network.

Considering our previous research with the latest version of CARMA locality metric [4], it is important to highlight its features in respect to what requirement they satisfy. We outline it as such:

1. Using RIR databases meet vendor-independence and open architecture clauses, because the RIR in their nature are mandatory and public domain information sources;
2. Building network model of national Internet segments conform to the open architecture clause, because the design details of the CARMA metric are publicly available, and to the decentralization clause because each node in the P2P swarm build the same model within its own memory;
3. The core methods for locality metric estimation conforms to the decentralization for the same reason and for the fast lookup clause because, evidently, locality estimation takes time in the order of seconds on modern hardware; this is reasonable given the fact that the calculation may be parallelized and connections may be scheduled according to the locality metric in the acceptable timeframe – and this is the essence of the P2P efficiency increase method too;
4. Usage of DHT under special circumstances of limited hardware capability conforms to the fast lookup and filter tolerances clause, since DHT interaction are not limited to the ICMP and could be potentially built over any transport protocol and NAT traversal schemes.

The overall complex of the proposed solution components is to provide for a number of expected qualities of the practical implementations. These qualities are: increasing throughput and lowering response latency due to higher level of clustering resulting in lowering inter-domain traffic and absence of the probing traffic due to the nature of calculation method.

Following open standard notion it is also important to provide software developers with easy integration interfaces for the locality metric framework. By avoiding closed-source components and implementations as well as any form of paid or restricted membership we achieve this goal.

Advancing the structural model

In our previous work [4] we have investigated the peering practices and the apparent ambiguity between ASSET membership and actual routing path that had led to the necessity to add one additional flavor to the CARMA flavor set, namely "Country".

It was noted that since national carriers sometimes are unwilling to either participate in traffic exchange points or establish mutually accountable peering partnerships with other local ISPs, the actual route path may cross several borders even for the address pair belonging to the same country and to the model entities formally registered under exchange point or related ASSET.

Even though this this flavor did indeed provided for leveraging advantages posed by the topological locality in cases of complicated ASSET linkage and peering conditions, the discrepancy between "ASSET", "Backbone" and "ASSET-Link" flavors remained significant, in the sense that "ASSET-Link" flavor had much less share in flavor breakdowns even for peer swarms concentrated in the same country.

To mitigate this issue we propose slight modification to the ASSET iteration algorithm. It was observed, that the number of associated ASSETs per input IP might reach hundreds, especially in the situations when multiple AS is listed as origination for that IP.

Previous "ASSET-Link" and "Backbone" validation algorithm only tested for one ASSET to include another using plain two-fold each-by-each comparison loop. This loop ends upon reaching the first declared match, who might not only be non-existentin reality, butalso not the only one.

We therefore suggest that for the class range between "AS-Link" and "Backbone" the class return value itself need not be an integer, but rather a real number indicating in its fractional part, for instance, the percentage of matching ASSETs relative to their lowest total amount per input node. Consider the following example: first node is found to be associated with 5 ASSETs, the second one with 7 ASSETs, and the number of matching ASSET pairs is two – i.e. two different ASSETs from first node is found to contain (or contained) two different ASSETs from the second node. In this case, the fractional part will be 0.4 as 2/5; This will be added to the regular class index of 5 (in 8-layer CARMA) rendering the result as 5.4.

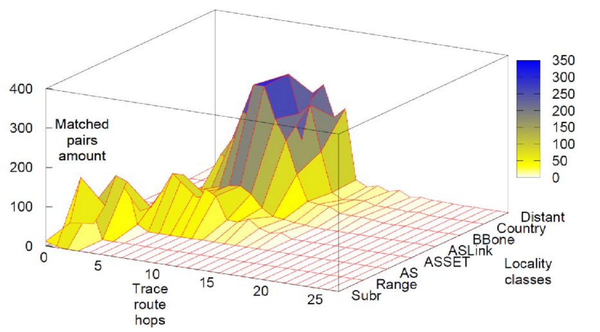
This will potentially allow for smoothing the discrepancy between class flavors by smoothing the difference between ASSET-Link cases and two classes closest to it.

Additional Experimental validation

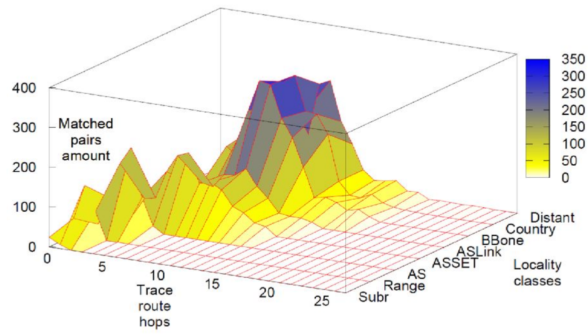
In our previous research [3] we have conducted a series of experiments aimed to establish a provable relation between CARMA metric expressed in flavor indices and traditional distance metric still in use today, namely standard *traceroute* method.

The previous version of CARMA has 8 flavors of no literal interpretation in terms of physical links or interfaces, and the experiments have conclusively indicated that there is indeed a relation, and by means of mathematical statistics it was estimated as significant.It was suggested that the observed correlation may differentiate daily with the variation of geographic distribution among swarm members. This could be caused, for instance, by different time zones of swarm participants and their desire to keep their hardware turned off for night.

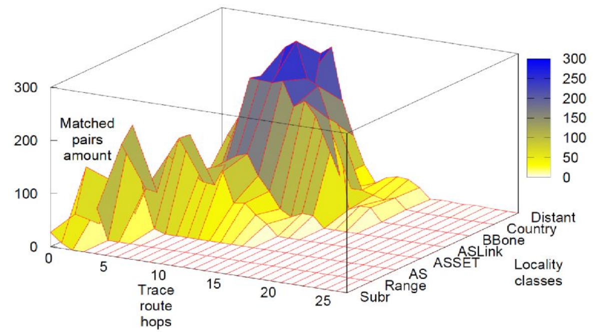
Therefore the original experiments were recreated under as closely matched circumstances as possible, only this time the validation runs were scheduled to start every 6th hour of each day during 10 days. The results were then grouped per 6th hour and averaged per day. The results are seen on fig.2.



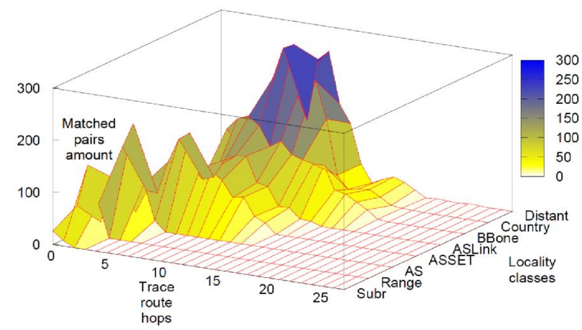
a) Correlation at 0:00



b) Correlation at 6:00



a) Correlation at 12:00



b) Correlation at 18:00

Figure 2. Daily dynamics of correlation between locality classes and traceroute transit counts; each graph is 6 hours apart.

Though no major differences were observed in these runs (by major we understand more than 20% peak decrease or shift), it is nonetheless worth noting that the total number of nodes paired with “Distant” flavor and transit ranges from 5 to 10 did slightly decrease during the evening time (18:00).

Since the primary node for these experimental runs was located in Ukrainian (GMT+2) Internet segment, this decrease is thought to be indicative of increasing daytime activities in the mainland United States (GMT offsets from -5 to -8), which accounted for 72% nodes in the “Distant” class. Since by 18:00 in Ukraine it was approximately noon in the continental U.S., P2P users there are likely to throttle down their download speeds or shutdown P2P clients to allow for uninterrupted service of other kinds such as VoIP and Video-on-demand.

Conclusion

In this paper we have provided the substantiation for the usage of general locality metric for P2P networks, citing the drawbacks that are common if existing unmodified methods are applied to solve this issue. Approach requirements are formulated and CARMA components and methods are referenced to meet such requirements.

The locality class is no longer an integer since it is possible to differentiate between two adjacent integer classes by analyzing the amount of matching pairs instead of stopping after having found just one. This will provide for further opportunities for fine-tuning locality metric between different adjacent classes, effectively making it a real number more suitable for mathematical analysis.

An additional experimental runs concerning the correlation between traceroute and CARMA metric were conducted but no significant variation was observed.

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