MobiCom 2010 Poster: Congestion Aware Data Dissemination in Social Opportunistic Networks

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This paper describes the design, development and evaluation an interest driven overlay on the top of our congestion aware forwarding protocol (CAFe) for social opportunistic networks. We show that P2P filecasting on top of Cafe achieves high success ratio of answered queries and high availability of intermediary nodes while maintaining fast downloads.

I. Introduction

Recent developments in social-based opportunistic forwarding [1], [2], [10] have identified that load is unfairly distributed towards nodes which are better connected. Unfair load distribution and high unrestricted volumes of traffic produce congestion. Congestion in opportunistic and delay tolerant networks takes the form of persistent storage exhaustion [1][4]. Several solutions exist including slowing sources, using alternative routes, discarding traffic, or migrating messages to alternative storage locations. We focus on congestion aware forwarding algorithms that adaptively choose the next hop based on contact history, predictive storage and delay analysis in order to distribute the load away from the storage hotspots and spread the traffic around. We describe new forwarding heuristics that uses nearby nodes with available storage and low delays to store data that would otherwise be lost during opportunistic bulk data transfers. More specifically we describe the two metrics Receptiveness and Retentiveness, each is a measurement of how utilised a node is, regarding node delays and buffer capacity respectively. Our heuristics factors in a cost metric associated with storage and delays so that the traffic is spread away from ego-network-centric paths and only paths with more storage and lower delays are chosen at times of congestion. Our heuristics makes use of the diversity of forwarding paths in human contact networks [7] by forwarding packets along multiple paths similarly to the resource pooling principal [6]. For our evaluation, we perform an extensive set of trace driven simulations for an opportunistic peer to peer file casting application. We build a realistic interest-driven P2P content dissemination overlay on the top of our congestion aware forwarding protocol. Our results show that our availability heuristics dramatically increases robustness of content distribution in terms of shorter download times and higher ratio of queries being successfully solved in the face of increasing congestion levels while still maintaining high availability among nodes when compared to SimBetTs[11] and Fairroute[4]. We induce congestion levels by increasing the topics popularity (number of randomly chosen subscribers) and the number of randomly chosen file publishers from 3% to almost 100%.

II. Congestion Aware Forwarding Algorithm (CAFÉ)

We first briefly describe our congestion aware protocol, CAFÉ, that works as a local forwarding protocol that diverts the load from its conventional social aware path and directs it via a different path that decreases the load and delays while keeping high success ratios. We extend our early CAFe prototype [10] that was driven by node storage only to include node delay considerations as well. When a potential intermediary node is about to get congested, CAFÉ determines the load and expected delays of a set of neighbours and chooses targets for offloading the messages. Depending on the contact, storage and delay history of the congested node, decision is made as to whether to offload messages to it or not. Two heuristics are proposed to be integrated with the social heuristics in order to select the alternative node that may select paths with higher hop counts but lower load and delay, and higher success ratio when answering queries. Our design of CAFÉ comprises two core components: 1) the Contact Manager that analyses and predicts the best nodes for forwarding based on their social positioning in the network, and 2) the Congestion Manager that detects and alleviates storage congestion and increased delays in intermediary nodes. These components work together in order to select which data chunks should be sent next and to whom. CAFÉ monitors and manages two buffers, the Forwarding Buffer and the Sender Buffer, this allows a fair distribution between forwarding the nodes own data and data from others.

II.A. Retentiveness

We define retention as the nodes ability to retain the packets that are sent to them, i.e. percentage of available storage. Our congestion control deters the use of nodes that have lower levels of availability and promotes the use of nodes with slightly less desirable social heuristic, but have greater level of available storage.

$$\mathrm{Re}t(x) = \lambda \cdot \mathrm{Re}t_{old}(x) + (1-\lambda)\cdot \mathrm{Re}t_{curr}(x) + \sigma \cdot W.\sqrt{1-\lambda^2} \quad (1)$$

Equation 1 shows our method for predicting the contact's remaining buffer. λ is the weight that identifies the degree of response, σ is the standard deviation of the buffer levels, W is a random number with zero mean and equal variances respectively and t represents time.

II.B. Receptiveness

We define receptiveness of a node as the exponential moving average delay that the node adds to the packets travelling by its aid.

$$Rec^{t}(x) = \alpha \cdot Rec^{t-1}(x) + (1-\alpha)\cdot T_d(P_x^t) \quad (2)$$

Equation 2 shows that we calculate receptiveness as the exponential moving average of the delay this node has added to the packets it has held. This value is updated each time a packet is successfully forwarded or is dropped. The intuition behind this is that the longer this node has held onto the packet for the more congested the network is, the duration of the delay will also depend on the level of connectivity in the network as well as the degree of congestion.

To manage tradeoff between social, retentiveness and receptiveness utilities during forwarding, we use a sum of each equally weighted utility as the total CAFe node utility in the following way:

$$CAFeUtil(X) = SocialUtil(X) + RetUtil(X) + RecUtil(X) \quad (3)$$

III. P2P File casting over Cafe: Design

We design, build and evaluate a socio-aware overlay that is interest driven and congestion aware to test Cafe. Our fully distributed file casting works as follows: each node that has content it wants to publish will give that content to the nodes that are interested in it and the nodes that known nodes that are interested in it as long as they have availability. If the publishing node does not meet any node interested in its topic for a while, it may cache its content in the highly connected and available nodes. Both caching and forwarding policies are decided based on the interest, availability and social closeness and numbers of other interested nodes. The caching policy requires more available storage and better connectivity with its contacts that share common interest. The heuristics behind it is that this will minimise the file chunks that the source sends to all interested parties, as it sends them only to intermediaries that can cache and distribute them faster and with lower traffic overheads. Our content is organised as in previous file casting work [5]: it contains topics and each topic has chunks that can be exchanged when the two nodes meet. Each chunk has an unique ID and the topic has the total number of chunks. We randomly assign topics to share and we choose random number of publishers. Nodes randomly choose to be interested in certain topics. The topics are disseminated based on the interest, social position of the nodes and connectivity to other interested nodes and storage availability. Similar work on publish-subscribe data dissemination in DTNs is [3] but that work explicitly relies on detecting communities and does not consider congestion control. Another similar work is [9] that proposes a content-based forwarding and buffer management based on content popularity but does not consider more congestion awareness and multiple sources. [9] add explicit application hints to messages that are visible to each intermediary DTN node, allowing them, e.g., to cache content, act as distributed storage, or perform application-specific forwarding. [8] approach allows generic functions such as bundle routing to be performed differently per application, operation, or resource, but particularly enables application support by means of caching or distributed storage. [8] work does not exploit and consider congestion aware forwarding.

IV. Experiments setup and results

Each node has a queue size of 1000MB and additional 100MB for caching. We have run FairRoute[2], SimBetTS[11] and Cafe on Infocom 2005 connectivity logs with increasing number of subscribers to different topics ranging from 3% to 100% and increasing number of file publishers ranging from 3% to 100%. All simulations are run ten times with different random subscribers and publishers. We compare the performance in terms of delays, success ratio, availability and number of caches across FairRoute, SimBetTS and Cafe.

Figure 1 shows that Café persistently achieves 280% higher success ratio of downloaded files compared to FairRoute and SimBetTS in the face of both increasing topic popularity (TP) and increasing number of file publishers (FP). Figure 2 shows persistently lower delays (above 155%) compared to SimBetTS and FairRoute in the face of both increasing number of publishers and topic popularity. This is due to our retentiveness and receptiveness heuristics. Figure 3 shows that Cafe has above 248% higher storage availability compared to the other protocols in the face of both increasing topic popularity and number of publishers. Café does not significantly decrease availability as the other protocols with increasing load. This is due to the increased caching rates for Café when compared to SimBetTS and Fairroute.

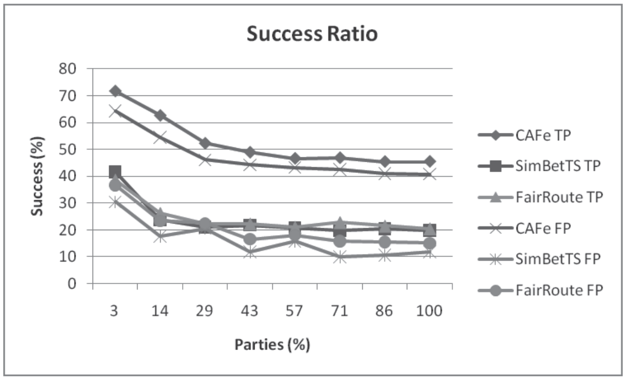

Figure 1 Success Ratio for varying topic popularity and number of publishers

V. Conclusions

Our early results are encouraging as Cafe manages to maintain high success ratio of answered queries, high availability of intermediary nodes and short download times for a P2P filecasting application running on it in the face of increasing number of file publishers and topic popularity.

We aim to explore in a greater detail the influence of relative in-network delays to the receptiveness and retentiveness in the presence of changing topology dynamics and other connectivity traces. Further work on new, intelligent application-dependent caching strategies and timeout mechanisms is needed to further improve the effectiveness and scalability of our congestion aware forwarding protocol.

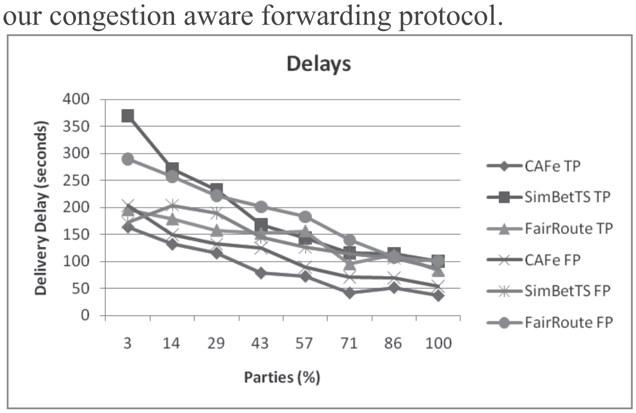

Figure 2 Delays for varying topic popularity and number of publishers

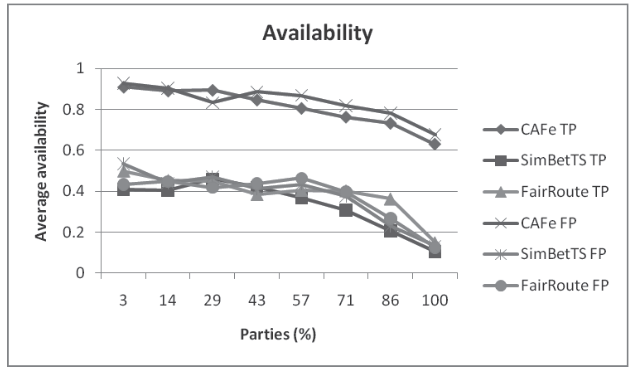

Figure 3 Availability for varying topic popularity and number of publishers

References

[1] A. Grundy and M. Radenkovic, "Decongesting opportunistic social based forwarding," in WONS, 2010

[2] J. Pujol, et al, "Fair Routing in Delay Tolerant Networks," in IEEE INFOCOM, 2009

[3] E. Yoneki, et al, "A socio-aware overlay for publish/subscribe communication in delay tolerant networks," in Proc. ACM MSWiM, 2007

[4] M. Seligman, et al, "Storage Routing for DTN congestion control", Wireless Communications and Mobile Computing, Vol 7, Issue 1,0, p1183-1196

[5] M. May et all, "Wireless opportunistic podcasting: implementation and design tradeoffs," in Proc. of ACM Workshop on Challenged networks. ACM, 2007, p. 82.

[6] D. Wischik et al "The resource pooling principle," SIGCOMM Computer Communication Review, 2008.

[7] V. Erramilli, et al, "Diversity of forwarding paths in pocket switched networks," in SIGCOMM, 2007

[8] J. Ott et al, "DTN-based Content Storage and Retrieval", In WOWMOM 2007

[9] Y. Jiao et al, "Data Dissemination in Delay and Disruption Tolerant Networks Based on Content Classification", in proc of MSN'09

[10] A.Grundy, M. Radenkovic, "Promoting Congestion Control for Opportunistic Networks", to be published in the Proc. of IEEE WiMob, October, 2010, Canada

[11] E. Daly and M. Haahr, "Social network analysis for information flow in disconnected Delay-Tolerant MANETs," IEEE Trans. Mob. Comp, 2009