P2P Replication Revisited: Mobile Infrastructures

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Abstract: Traffic engineering in P2P networks deals with organizing overlay networks. The challenge of unavailability has not been mastered yet. Considering the resource allocation can gain further improvements. While adapting P2P file sharing onto mobile infrastructures, we learned that replication is a solution to both issues: availability and traffic optimization.

1 Introduction

Today, P2P file sharing produces the largest share of Internet traffic. Mobile P2P might become the killer application that boosts mobile Internet. We examine replication on mobile infrastructures and derive new insights into P2P replication on generic networks.

The robustness and efficiency makes the peer paradigm interesting to both operators and users. P2P technologies exploit underlying design principles from wired networks as the Internet. Future mobile networks, especially GPRS/UMTS networks, require a new adaptation of peer concepts, as their infrastructure fundamentally diverges.

Peers communicate with a few neighbors and build up an *overlay network*, which transports information to other peers. The topology is usually determined statically, either by random or derived from network characteristics. These approaches manage to improve generic P2P traffic, but do not analyze traffic flows in detail.

	upload	replication management	resource allocation view
eDonkey	local, super peer update	user	on request
BitTorrent	local, tracker setup	user	in detail
Freenet	release first copy	access history	concealed
DHT	store replicas	fixed	implicit

Table 1: Replication in P2P Systems

Overlay network peers process store-and-forward operations and thus popular information might be repeatedly transmitted. We investigate replication in file sharing systems, where any peer has only a very small subset of resources. Replicas do only exist on nodes, where

users manually started the resource download (cf. Table 1). Such a replication on user demand can result in poor resource allocation, if a seldom resource is only shared from low availability peers, e. g. a cellular phone application. This paper considers establishing replicas in mobile P2P file sharing systems.

Our project scope has been the GPRS/UMTS networks. Wireless networks in general must be considered separately, as their bottlenecks have different characteristics. However, replication will be relevant to all networks that heavily diverge in their physical network structure.

2 Related Work

Pastry [CDHR02] and the topology management approach [FMA03] efficiently reduce the connection span. Lamehamedi et al. attested dynamic data replication as a valuable principle in GRIDs [LSSD]. Ratner et al. specified in the ROAM project selective replication for mobile environments [RRPK01]. The JoltID peer cache is a proxy that caches P2P communications [J03].

In Freenet, introduced by Clarke et al., data is actually relocated [CSWH01]. A node stores data which has been repeatedly transmitted from neighbors. Information moves dynamically towards recipients. Replication is organized distributed and because of sender anonymity, the Freenet design does not guarantee to retrieve stored data.

3 Mobile Infrastructures

Mobile networks like UMTS and GPRS utilize hierarchical routing. Each provider network has entry points called Gateway GPRS Support Node (GGSN). The GGSN acts as an indirection node for all traffic on the GSM and UMTS Radio Networks, even if communication partners physically reside inside the same cell. This hierarchical network design enables mobility, but it urges all traffic to go through a single node.

	mobile networks (2.5/3G)	mobile networks (802.11x)	wired networks
routing	strictly hierarchical	-	topology based
host classes	mobile/core	mobile/fixed	-
intra-class com's	2x backbone	air-to-air	shortest path
inter-class com's	1x backbone	access point	shortest path

Table 2: Network Structure Properties

When examining P2P file sharing on mobile networks, we found enhancements that can be achieved easily. Table 2 summarizes the differences between 2.5/3G and other networks.

Note, that communications between mobile devices in 2.5/3G networks have double network resource usage compared to server communications, if these are located in the core network. This is a major contrast to today's Internet, where physical network positions have few influence on application efficiency. We found that placing replicas on servers in the core of the mobile network can heavily reduce the network load.

Previous work controlls P2P traffic load by constructing overlay networks. Efficient overlays result in logical topologies that map onto the underlying physical network. Because mobile-to-mobile connections do not gain advantage of physical neighborhood (always routes through the GGSN), topology optimization would not be effective here. However, if we place a peer at the network core sharing popular resources, we gain considerable savings of popular content on the core network. Additionally traffic exchange with outer networks is reduced; traffic is kept locally.

We found that resources replicated at a GGSN-near peer would be distributed much more efficient. Our P2P-enabling mobile architecture introduced the cache peer which retrieves and shares popular resources at the network core. The eDonkey prototype utilized the mediation service, provided from the super peer, to produce statistics and forecast future accesses. The cache peer automatically downloads these resources and makes them available at the GGSN. The simulations show that downloading from a network-core peer extensively reduces the traffic load [AdMD+04].

Summarizing, the hierarchic structure of mobile network infrastructures suggests replication and its application can gain improvements with significant economical impact. Because of the strictly hierarchical network structure only nodes at the core network are feasible for replica placement.

4 Lessons Learned

Optimal replica allocation raises two questions: *what* resources should be replicated? The resource selection depends on future requests, but also on the current allocation. Second, *where* should these replicas be positioned?

File sharing systems with centralized mediation offer their statistics, which gives a cheap approximation for future resources accesses. Two current mechanisms allow a *global allocation view*. The BitTorrent trackers obtain detailed allocation information from all current leecher and seeders. The eDonkey file sharing network offers similar, but not as fine-grained information. Here it cannot be distinguished whether a peer shares or requests a file and the global allocation remains unknown until direct communication to all peers has been established. Current approaches drop information when peers are considered offline, The low availability in mobile environments suggests an *online and offline allocation map* that also states resources that are not currently accessible.

Replication in networks with hierarchic routing should be close to the network root, e. g. to the GGSN in 2.5/3G infrastructures. Future work will continue into placement algorithms on generic networks. While detailed allocation information is essential for replication, it also raises strong privacy issues as it includes references to the physical network.

The projects raised discussions on tariffs and digital rights management (DRM). Current mobile traffic rates make P2P unattainable, but we strongly expect this to change in next years. Network operators are in need for a widespread application with high user acceptance, which P2P sure is. Although digital rights management has not been in scope of our project, we believe that future developments will overcome the current legal disputes. A replica might store encrypted fragments. By this the replica peer operator cannot be held responsible. One solution is a one-way encryption of content IDs, such that peers can find encrypted replicas, but servers cannot decrypt replicated data. In the next years research will contribute solutions for DRM, meanwhile the P2P community evolves independently.

5 Conclusion

Peer-to-peer systems successfully operate in wired networks. However, they show expensive network resource usage on hierarchic infrastructures like 2.5/3G infrastructures. Placing replicas on the network can efficiently reduce the network load and allows operators to keep P2P traffic locally. In UMTS/GPRS networks replicas should be placed in the core network. The low availability of nodes can be overcome by extending the allocation map to offline nodes to. Replication will be a good choice when it comes to P2P on mobile infrastructures.

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