

Segmented File Sharing with Recursive Epidemic Placement Policy for Reliability in Mobile Peer-to-Peer Devices

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Abstract

Peer-to-Peer applications have become highly popular in today's pervasive environments due to the spread of different file sharing platforms. In such a multicient environment, if users have mobility characteristics, asymmetry in communication causes a degradation of reliability. This work proposes an approach based on the advantages of epidemic selective resource placement through mobile Infostations. Epidemic Placement Policy combines the strengths of both proactive multicast group establishment and hybrid Infostation concept. With epidemic selective placement we face the flooding problem locally (in geographic region/landscape) and enable end to end reliability by forwarding requested packets to epidemically 'selected' mobile users in the network on a recursive basis. The selection of users is performed based on their remaining capacity, weakness of their signal and other explained mobility limitations. Examination through simulation is performed for the response and reliability offered by epidemic placement policy which reveals the robustness and reliability in file sharing among mobile peers.

1. Introduction

The nowadays ubiquitous presence of mobile phones and PDAs equipped with close range radio connectivity like Bluetooth and WLAN create a fertile research environment for ad hoc networks. These kinds of networks are very flexible and suitable for several situations and applications forming a dynamic infrastructureless network without any preinstalled components. Recently, peer-to-peer networks have become extremely popular as a way to share with other Internet users. Each user installs and runs an application that lets them define objects to share and distribute queries to other users on the network.

While (Mobile Peer to Peer) MP2P objects sharing is user driven as happens to the internet, a crucial issue is which dissemination strategy will be used. MANets due to the frequent and unexpected changes in topology and short lived devices characteristics are not robust to host with reliability resource/file sharing among mobile peers. Thus by applying epidemiological models to information diffusion allows the evaluation of such strategies depending

on the MANET characteristics, e.g. the node density. In order to choose appropriate strategies at run time, the model should be easily evaluated. Reliability in highly changing topology networks is a major issue since their moving characteristics trade off the end user's QoS. Thus optimally designed systems have to offer end user reliability and integrity by enabling reliable sharing of information.

In an infrastructure based wireless systems hosts are purely connected and "long lived". However in wireless systems where no infrastructure exists like MP2P systems hosts/devices are "short-lived". Connections between peers on the network are prone to failures while this is aggravated by short connections times, unpredictable disconnections (range and battery failure), small network formation factor, and file's unavailability.

In this paper an epidemic selective placement policy for reliable file sharing for MP2P devices is proposed taking the advantages of epidemic file dissemination through mobile users and mobile Infostations [1, 10]. Through geographical landscapes where mobile Infostations are set and initialized, the modified epidemic protocol creates a replicated object in order to enable MP2P reliable file sharing. Mobile Infostations called Primary Infostations are chosen based on their velocity, residual energy, remaining capacity etc. This scheme proved its scalability in node's density since it does not require the knowledge of network at any single host. The paper is organized as follows: Section 2 discusses the related work that has been done for MP2P reliable information sharing through different proposed schemes, Section 3 presents the proposed epidemic segmented file sharing using recursive placement scheme for MP2P users. Section 4 provides the evaluation and simulation results of the proposed scheme in contrast to the epidemic replication characteristics and quantitative comparisons with other schemes applied in literature for MP2P environment. Finally, Section 5 concludes with a summary of our contribution.

2. Related work

Swarming different wireless peers in an infrastructureless environment could enable significantly better reliability response and at the same time reduces the failure inclination. Wireless devices must be able operate for extended periods of time unattended, where evolving analysis and environments can change application requirements, creating the need to alter the network's

behavior. Roughly speaking every node in wireless networks act as a router where in most cases routing decisions are based on a specialized queries to adjacent users. Therefore spatial knowledge is required for the whole network in order to enable any node to have the ability to reach any other node in the network (anycast). Of course resource sharing process should require a minimal amount of time. This not only reduces any service interruptions to a deployed application, but is also reduces information sharing reliability. Recent researches in reliable information sharing require dense networks in order to bind network partitioning. However, in dense networks, the contention and collisions caused by the random interactions of neighboring nodes harms the performance since file sharing techniques rely on overhearing. In turn overhearing drives the network to generate a huge overhead in order to “hear” the peers. This issue can be disastrous for sensitive information since capacity limitations can take place in each node due to overhearing, and information will be lost¹.

Information diffusion policy must be based on each node’s state and also on the cooperation degree with other nodes. As examined in [2] naive retransmission of broadcasts can lead to the broadcast storm problem, where collisions impair performance and reliability. The authors in [2] discuss the need to have a controlled retransmission scheme and propose several schemes, such as probabilistic and location based methods. Flooding in a wireless network is in fact as efficient as wired networks because of wireless multicast advantage. The experiments were conducted by Ganesan et al. In [3] authors identify several interesting effects at the link-layer, notably the highly irregular packet reception contours, the likeliness of asymmetric links, and the complex propagation dynamics of simple protocols. Improvements of the basic flooding approach using advertisements and geographic information have also been recently studied [11,20]. In [4] an epidemic algorithm is proposed based on strictly local interactions for managing replicated databases in a robust way for unpredictable communication failures. The metaphor of epidemic property to wireless systems is important since MP2P devices experience high loss rates due to their unpredictable movements, their asymmetric connectivity, and to node failures in the “repopulation” process [5]. When a mobile node makes an explicit request for a resource, the whole network is flooded with a query, like mobile ad-hoc route discovery algorithms [6]. In [7] data replication schemes are proposed for ad hoc networks which are based on the improvement of data accessibility. However, this approach may not be valid when the link failure probability is taken into consideration. Another drawback is that it only considers the accessibility, without considering the query delay. Significant improvements of the basic flooding approaches using advertisements and geographic information have also been recently studied [8]. In this work we propose a dynamic gossiping way for reliable autonomous file sharing. This scheme uses the new concept of mobile Infostations where is a variant of fixed Infostation proposed in [1, 11, 13]. The main difference from our previous work [24] is that the main (Primary-PI) Infostation

is not static, and packet’s placement occurs recursively meeting some criteria as will be explained. In this work the PI can move in a certain location or circle radius R . Indeed the file sharing mechanism is essentially stateless, where neither routing information is required nor global information like knowledge of the destination nodes is required. By adopting the idea of geographical landscapes where initialized Infostations are set in, the modified epidemic protocol creates a replicated object to mobile Infostations in order to enable P2P reliable file sharing in an “any cast” form.

3. Epidemic segmented file replication for maintaining reliability in mobile Peer-to-Peer devices

The goal of our protocol is to ensure reliability in file sharing in adjacent geographical landscapes in an epidemic way. The novelty of this scheme is that it combines the strengths of both proactive multicast group establishment (flexible Geocasting) and hybrid Infostation concept and attempts to fill the gap between mobility and reliable file sharing for mobile peer to peer users. This method faces the flooding problem by forwarding requested packets to epidemically ‘selected’ (epidemic placement) mobile users in the network under different conditions analyzed in the following sections.

3.1 Cooperative mobile Infostations in organized landscapes

When delay sensitive packets/multimedia streams are sent from a wireless device to another, the end to end communication must offer sufficient reliability and integrity. Short-range wireless communication technologies such as wearable PCs demand low latency and reliability as the first thing for considering QoS. The nowadays concept of "run anywhere, anytime, anything" particularly in pervasive systems, demand ensured QoS. Such systems are based on the waterfilling concept, where the transmission occurs only when source and destination are close together to ensure reliability. In [1, 9, 11] researches have provided good estimates that permit such systems to become the basis for low cost, wireless data transmission.

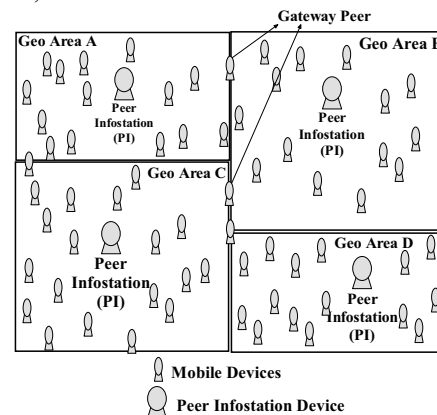


Figure 1: Geographical landscape with the hybrid Infostation model.

¹ The same time security issues arise.

Wireless networks due to device limitations have constrained capacities and bounded capabilities in terms of networking. Some problems are the mutual interference of concurrent transmissions between nodes, security and reliability issues arise on a mobility based scenario. Some research results presented in [10], introduce mobility into a fixed network model, which show that the average throughput per source-destination pair can be kept constant even if the number of nodes per unit area increases. This improvement is obtained through the exploitation of the time-variation of the user's channel due to mobility. The new concept in [10] is to split the packets of each source node to as many nodes as possible. Therefore, strategies of this type incur additional delay, because packets have to be buffered until the channel becomes sufficiently strong for transmission(s). Taking into account all the above reasons, this paper adopts the idea of Infostation into geographical landscapes. Figure 1 shows the basic mobile Infostation model applied in a geographical landscape.

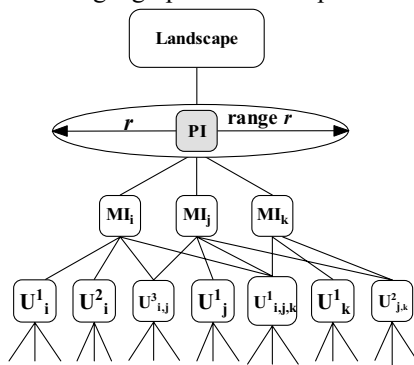


Figure 2: The hybrid peer-to-peer Infostation based architecture (HyMIS).

A good idea is to enable broadband hotspots in a centralized form. This concept is already implemented through Infostations [1, 13]. Infostations consist of high bit rate connectivity which can be seen as independent access ports to the Internet, or (clustered) organized into groups having a common server (Cluster Infostation Controller-CIC). Different locations and characteristics of user mobility patterns for different scenarios are depicted in [11, 12]. In such scenarios² the controllers are connected to the internet through a backbone network. Combining the pure Infostation system with a mobility based framework we introduce the Hybrid Mobile Infostation System (HyMIS) where the primary Infostation is not static (PI) but can move with lower velocity³ than other selected Infostations (totally different approach than in [24] where fixed Infostation (FI) exists in each landscape and placement policy does not occur recursively). Furthermore, secondary Infostations could move across an area forming a cluster with other peers (geo-Peering) and exchanging information with PI of each landscape. PI is selected only if it set in the centre of the landscape/geographic area. Additionally PI covers only a specified circle of radius R (figure 2). The R radius coefficient depends (as in all mobile hosts) to signal power.

² The drive through, the walk-through, and sit-through scenario(stationary users)

³ That might be research criterion for selecting a device to be PI.

All other nodes move freely in the landscape or in any other landscape. HyMIS architecture resolves the disadvantages of the pure MP2P architecture in terms of inefficient routing, network partitioning and lack of security.

HyMIS adopts the basic concept of pure Infostation system in terms of capacity node but without flooding the network with unnecessary flow of information. This capacity node plays a role of control storage node [13]. On the contrary to [13] this work proposes a hybrid peer-to-peer architecture shown figure 2. PI is selected⁴ and located in the center of every landscape covering a certain predetermined area. A mobile peer is chosen to be PI only if it has high residual energy and capacity and moves with low velocity (or stall). This means that for a certain time distance T (until it remains as the PI of the landscape) will be near or located at the centre of the landscape⁵. Additionally Mobile Infostations (MIs) are set dynamically, based essentially on the residual spare capacity as is explained in the following section. These MIs are users that are in the landscape creating a tree of MIs users and PI users. This principle is shown in figure 2. As depicted in figure 2, $U^{1,i,j,k}$ is downloading simultaneously from MI_i , MI_j , MI_k or vice versa. The coexistence of PIs and MIs (that do not change landscape every while) simultaneously recovers from the partition of MP2P network. The idea of directing copies of requested data to a certain group of nodes aims to keep network services reliable and storage costs minimal whereas there are some possible expenses for data retrieving like the effort to find and retrieve a data item.

3.2 Recursive epidemic object replication placement scheme for reliable file sharing

By using undirected dissemination policy we simply distribute the requested resources to users without ensuring that candidate node will be reached or even if it is reached, the availability is no longer valid due to frequent changes in topology. It is highly important that a certain information or group of information (file(s)) have to reach one particular host or all hosts within the entire network. Directed dissemination scenarios, or epidemic algorithms, which follow a nature paradigm, enable local view of the environment. According to this fact, epidemic algorithms are easy to implement and guarantee message propagation in heterogeneous environments.

Infrastructureless peer-based wireless networks can be used as a cache based infrastructure, in a way that the contents can be discovered in a peer-to-peer manner whenever possible, instead of each user individually downloading it from a peer or peers. Reliability in file sharing can be determined by relying on epidemic algorithms, a breed of distributed algorithms that find inspiration in the theory of epidemics. Epidemic (or gossip) algorithms constitute a scalable, lightweight, and robust way of reliably disseminating information to a recipient or group of recipients, by providing guarantees in probabilistic terms.

⁴ Selection is based on the low velocity criterion and trajectory of each device

⁵ We assume that each node is informed about reaching each Landscape's centre and also if is candidate to become a PI.

Particularly it enables a virtual motoring of a group of devices sharing common resource(s) (or “infections” see figure 2). Based on certain characteristics, epidemic algorithms are amenable to the highly dynamic scenarios. In this work a promiscuous caching is used which means that data can be cached “anywhere, anytime”. However this enables trade offs in consistency for availability which is faced with cooperative MI used in landscapes described earlier.

The key issue for any proactive dissemination scheme is to provide a mechanism so that mobile hosts do not have to search for resources when they are needed, but rather in a way to have them automatically extracted (pushed). In epidemic diffusion, instead of mobile nodes making the decision to push data to each other, it is the data items themselves that try to identify other hosts which are suitable, based on the data item’s own profile and host’s advertised profile. In wireless networks a user might desire to share or download a file or files with other users (peers). Many conditions must be satisfied for reliable communication between mobile peers. On one hand users due to their mobility might draw away from the user (peer) that a file sharing communication takes place. On the other hand a sudden network partitioning or network split could occur because of network’s dynamic topology which is continuously changing. Thus a proactive dissemination scheme must be determined in order to prevent the cutoff in file sharing communication. This work assumes an isolated system comprising of a fixed number of mobile nodes confined in a predefined geographic region. These nodes are mobile, and communicate with each other in a wireless (radio) ad-hoc manner. As studied in [8, 10, 12] there is a trade off between reliable coverage and data rate. The limited connectivity coverage that MP2P systems offer, results in significant delay in downloading a message or file (group of packets). In the proposed scenario each node carries some unique data items. During the period for which the system is studied, no new node is inserted in the network.

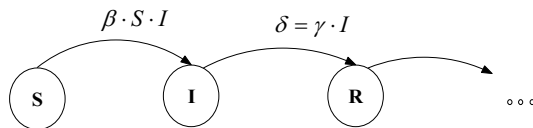


Figure 3: Markov chain model of an infectious disease with susceptible, infected, and recovered states.

A mobile host m_k has a predetermined capacity M and a state. There are three states that m_k can be characterized: the susceptible state $S(t)$ represents the number of hosts in the system which are “susceptible,” infected state $I(t)$ represents the number of “infected” hosts, and $R(t)$ represents the “recovered” hosts. A host is in susceptible state $S(t)$ if the device does not share any information with any other host. In turn A host is in infected state $I(t)$ if a file(s) share occurs. Finally a host is in “recovered” state $R(t)$ if any shared file(s) are no longer pending. A Markov chain model of an infectious disease with susceptible, infected, and recovered states is used shown in figure 3. Markov chain model was chosen to evaluate this extra

storage requirement, for modeling of infectious diseases to determine the file sharing termination criteria.

The modelling of diseases in fixed networks have been studied in the past [14], and this model is used in a similar manner in this scenario. Adopting the framework from an infectious disease model [15], a host is set as “infected” if a file sharing (or a group of data packets) are pending. Suppose there are k hosts in the system, then a host is sharing a resource with $\beta(k-1)$ other hosts per unit time. $S(k-1)$ do not have yet the disease. Therefore, the transition rate from state S to state I becomes

$$\text{Filesharing} = (nu_infected) \cdot (dld_Rate) \cdot (nu_NOT_share) \quad (1.1)$$

$$\text{Filesharing} = I[\beta(k-1)] \cdot \left[\frac{S}{k-1} \right] \quad (1.2)$$

where β is the contact rate for k hosts.

Then the downloaded (no longer pending) rate is:

$$\delta = \gamma \cdot I \quad (2)$$

where γ is the download rate and I is the number of infected devices.

The $\beta \cdot S \cdot I$ is called π coefficient which indicates the enforcement degree of the diffusion process. π has the dimension of $\left[\frac{1}{Time} \right]$. Previous examinations of the

behaviour of small scale systems [15] showed that relatively small populations could be faced with a stochastic model. Thus taking into account that π depends on the number of $S(t)$ and $I(t)$ and the probability of transmitting the information, we can derive $S(t)$ as follows:

$$\frac{dS}{dt} = -\beta \cdot S \cdot I = -\pi \quad (3.1)$$

$$\frac{dI}{dt} = \beta \cdot S \cdot I = \beta(N-I) \cdot I = \beta NI - \beta I^2$$

By solving the first order differential equation the outcome is:

$$I(t) = \frac{N}{1 + e^{-\beta \cdot N \cdot t} (N-1)} \quad (3.2)$$

According to the definition of spreading ratio equation (3.2) becomes:

$$I'(t) = \frac{I(t)}{N} = \frac{N}{N \cdot (1 + e^{-\beta \cdot N \cdot t} (N-1))} \quad (3.3)$$

$$I'(t) = \frac{1}{1 + e^{-\beta \cdot N \cdot t} (N-1)}$$

Equation 3.3 is referred as the cumulative distribution function.

An issue is when the locations will be updated. This issue can be measured as follows:

$$L(t) = L(t-1) + S_t \cdot \vec{d} \quad (4)$$

where $L(t)$ is the new location $L(t-1)$ the previous location at step time $(t-1)$, S_t is the speed of each device and \vec{d} is the directed unit vector [13]. Additionally the distance from a node to the closest PI can be measured as [(Node’s position - center of PI’s communication area) - (radius of area)].

4. Simulation experiments and discussion

To demonstrate the methodology discussed in this paper, we performed exhaustive discrete time simulations of the proposed scenario under several different conditions. In the implementation-simulation of this work we used our own libraries implemented in C programming language. We have modeled and simulated (based in C/Objective C programming language) the previously discussed scenario soundly based on our source code and our C libraries built.

We assume a system consisting of several mobile nodes, e.g., mobile users equipped with notebooks or PDAs and wireless network interfaces. All mobile nodes collaborate via a shared application that uses a distributed lookup service. Radio coverage is small compared to the area covered by all nodes, so that most nodes cannot contact each other directly. Additionally, we assume IEEE 802.11x as the underlying radio technology. However, it is necessary to point out that communication and epidemic-like dissemination could be employed on any radio technology that enables broadcast transmissions inside a node's radio coverage.

4.1 Routing protocol used

In the implementation of the proposed scenario the Zone Routing Protocol (ZRP) [19, 20] is used. The ZRP is considered advantageous because allows to a certain node to accurately know the neighbors of any mobile terminal within a zone (PI-like approach [1, 2, 6, 19]).

4.2 Simulation and performance evaluation of the proposed scenario

To emulate the scenario described earlier, the need of a possible realistic environment must be achieved. In this section, we present some experimental and simulation results for performance evaluation and reliability in resource sharing offered by our scheme.

Two sets of experiments were performed. One set deals with the epidemic selective placement concept and the grade of contribution in enabling reliability in file sharing, and the second deals with the performance of recursive epidemic object replication placement under significant traffic, network partition limitations and the latency issues that arise. As mentioned the caching capacity of each node could be unlimited while nowadays memory becomes cheaper and cheaper. However if each node has unlimited capacity then enormous traffic will reach each node's buffer causing "vicious" dissemination in a bounded node network. Thus taking into account this issue, this paper evaluates two different types of caching capacity:

- (i). Unlimited capacity
- (ii). Limited capacity for each node as 64KB, 128 KB, 512 KB, 2 MB, 10 MB.

An issue that has to be taken into account is whether the cached information destined for a proper node could be stored in a node with higher residual energy. As shown in simulation process if nodes with higher level of residual energy are chosen in the path then the network partitioning

probability is further reduced [21]. For this reason cached information size and file size are chosen randomly in our scenario and files are searched for, upon queries on a recursive basis.

In simulation was used a two-dimensional network, 4 landscapes each one consisting of 25 nodes with each link (frequency channel) having max speed reaching 2Mb per sec. The propagation path loss is the two-ray model without fading. The network traffic is modeled by generating constant bit rate (CBR) flows. Each source node transmits one 512-bytes (~4Kbits-light traffic) packet. Packets generated at every time step by following Pareto distribution as depicted in [17-19], destined for a random destination uniformly selected.

Additionally we have modeled in each node an agent which evaluates the information destined for a proper destination. In this way we have at any time measures of the information destined for each node (for a given time interval) by any node. In real time networks this agent could be client-based. Network structure has been implemented as a [N-1] row, [N-1] column for each node being a possible destination as developed in [21].

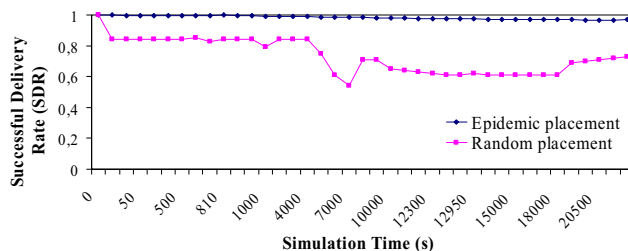


Figure 5: The ratio of successful packet delivery.

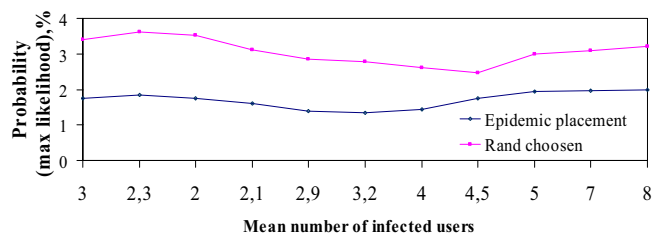


Figure 6: Mean number of infected users in the landscape.

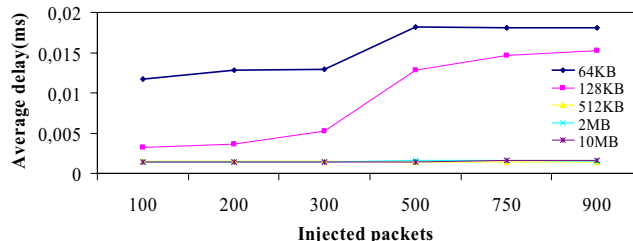


Figure 7: Average packet delay versus the number of injected packets in the network.

Figure 5 shows the successful packet delivery ratio. It is clearly shown that throughout simulation time the SDR drops slightly using the epidemic placement. Compared with randomly selected users (even for cache placement or) the epidemic diffusion behaves significantly better. After consecutive simulations the extracted values did not

dropped below 96.5% for successful delivery of packet. Future research will examine the behavior for random and epidemic selection under self similar traffic (web traffic [18]).

Figure 6 illustrates the mean number of infected users, infected by epidemic algorithm used and by randomly chosen selection, in the landscape. As seen the mean number of infected users for which epidemic algorithm is used is significantly small compared with the number of randomly chosen. This proves the robust characteristics in node selection for packet's caching in order to enable reliable file sharing.

In figure 7 the average packet delay with the number of injected packets in the network is illustrated. As the number of packets increases the average packet delay increases slightly. After consecutive simulations for this metric it has been shown that when the number of injected packets reaches 550-600, the average packet delay increases dramatically for 64KB and 128MB capacities. This occurs due to capacity limitation that binds each node. As shown for different capacity limitations the average delay remain almost the same for 128KB, 512KB, 2 MB and 10 MB.

Figure 8 shows average packet delay with the corresponding cached capacity for different cache placement strategies. For the comparison we used the generic cache replacement policies of Least Recently Used (LRU), Size replacement Strategy (SRS), Least Frequently Used (LFU). LRU is tested for when the copied file is least recently used (the cached item is associated with a time stamp). SRS is tested by aggregating the large files which in our scenario the concept large is equal to $0.33 * Total_remaining_capacity$. Finally LFU strategy evicts the aggregation to cached files which are accessed least frequently. Figure 8 depicts that epidemic approach behave sensibly better for small files and satisfactory for relatively large files.

In figure 9 the average packet delay using the LFU "aging" placement factor compared with epidemic placement and pure LFU, is presented. Some cached items may be heavily used or only used during a limited time in t . In such a case, those items may stay in host's cache for a long time ($t_{item} \leq t$), even though they are no longer being used. By using aging factor we alleviate this problem. A decay function is used to decrease the 'reference count' as the time passes. This corresponds to an exponential half life as $AgeFactor = 2^{-\frac{age}{Time}}$, where age is the current age of the cached item and $Time$ is the aggregation time that passed. Experiments were performed for LFU, Epidemic placement and LFU with aging factor. It is shown that epidemic object replication placement behaves significantly better compared with LFU with aging factor and LFU. Even with 70MB cached in an epidemic form this scheme is robust with less than 0.15msec average packet delay.

Figure 10 shows the percentage of successfully transmitted packets using epidemic selective caching versus the mean number of disturbed files. It is remarkable to point out that for large number of file distributions the percentage of successfully transmitted packets using epidemically selective placement does not drops below 76.8%. This

means that for large distributions in any landscape the packets can be successfully transmitted in high percentage compared with other schemes [1, 5, 11].

In figure 11 the average number of segments per file versus the capacity of each file is illustrated. It is easily extracted that for large files (>1MB), the segments which are randomly chosen depending on each file chunks, are not exceeding 64. From figure 11 it is indicated that small files can be segmented (in ratio) in much more pieces than for large files. This results a better reliability response in many consecutive simulation's potshots.

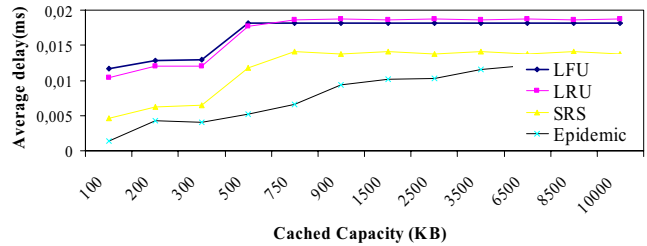


Figure 8: Average packet delay for different cache placement strategies and the corresponding cached capacity.

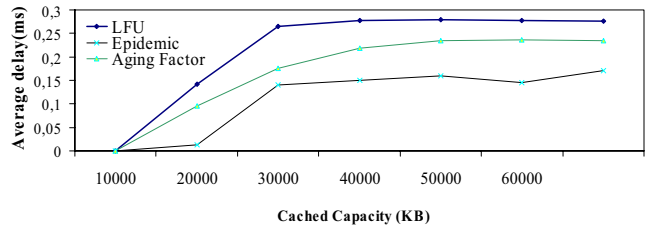


Figure 9: Average packet delay for LFU "aging" placement factor compared with epidemic and LFU with the corresponding cached capacity.

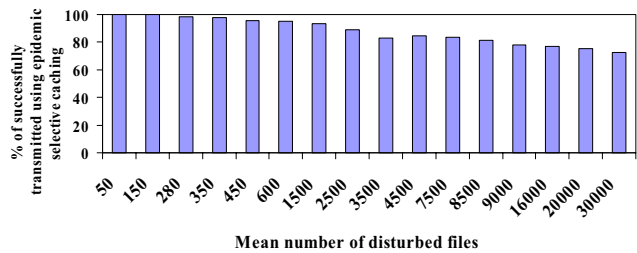


Figure 10: Mean number of disturbed files with the number of successfully transmitted using epidemic selective caching.

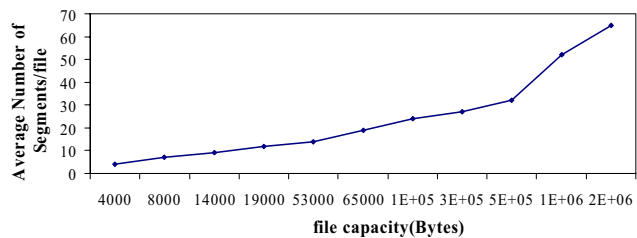


Figure 11: Average number of segments/file versus file capacity.

5. Conclusions and further research

Even if the research performed up to now in MP2P networks field is basically network centric, we propose the idea of resource driven communication instead of IP driven point-to-point communication/resource sharing. We merged the metaphor of epidemic file dissemination through mobile users with the concept of mobile Infostations. The proposed recursive epidemic placement scheme creates a replicated object in order to enable P2P reliable file sharing. By using epidemic recursive placement scheme to moving P2P devices the file sharing reliability significantly increases as opposed to [22] where no placement policy is used. Additionally this scheme proves its scalability in nodes' density since it does not require spatial distributions to efficiently spread information while enables reliability in supported mobility.

This research could be extended for mechanisms that are variously known as match making, geographic hash tables (GHT) or even for content based multicasting (CBM). Each landscape can host a central hash table for content users and can reliably locate any file to epidemic users. Additionally epidemic placement could be modeled and applied to large scale systems like internet-2 where dynamic access to cached pages could be requested by mobile hosts.

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