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People
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Worst-Case Performance Analysis of Web Service Workflows

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Abstract:	One major challenge in business process intelligence and business process management is performance modeling and performance measurement of workflows in order to plan their execution. Business process intelligence facilitates advanced business process execution management, i.e., prediction, monitoring, and optimization. In order to analyze Web Service workflows and to plan the workflow control, network calculus, originally developed for analyzing packet switched networks, can be used to describe the worst-case performance behavior of a workflow. By addressing capacity planning of Web Service workflows, resource usage becomes more and more important. Performance modeling and measurement are crucial to ensure that the workflow execution remains feasible and SLA violations due to overload are avoided. Thus, this paper presents a worst-case performance modeling approach for Web Service workflows based on network calculus to support capacity planning decisions.

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ECHoP2P: Emergency Call Handling over Peer-to-Peer Overlays

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Abstract

The impact of the peer-to-peer paradigm increases both in research and in industry. Still, serious applications for P2P-based systems are rare. On the other hand, Emergency Call Handling (ECH) is (or will be) a mandatory function for VoIP services. In this paper we investigate international legal and technical requirements of ECH and present ECHoP2P, a solution that fulfills these requirements. Based on Globase.KOM and HiPNOS.KOM, ECHoP2P provides the functionality to determine the closest and (geographically) responsible Emergency Station to a calling peer. Further, Emergency Calls are processed with highest priority in the overlay, so that quality of service guarantees are given. We evaluated ECHoP2P thoroughly and present the quality and costs analysis, identified tradeoffs and effects of optimization parameters. ECHoP2P provides a fully evaluated solution for Emergency Call Handling and for further location-aware applications.

1 Introduction

Peer-to-Peer (P2P) applications are emerging and more and more commercial applications based on the P2P paradigm arise. However, P2P systems often do not provide any guarantees in any terms of quality of service (QoS). Hence, the P2P paradigm is often applied to private, non-critical applications. File-Sharing, collaboration and communication using P2P systems are often for free, but without any guaranteed service. In order to increase the impact of the P2P paradigm, research has to turn towards serious, commercial applications. In this context Voice over IP (VoIP) telephony has to be seen as application area for P2P architectures. VoIP telephony is revolutionizing the telephony market [1] since the upcoming of the P2P based telephony software Skype [2]. With Skype phone calls can be made over IP (from one Skype user to another) for no additional costs. In addition, more and more telephony providers change to VoIP technology, giving up usual Public Switched Telephony Networks (PSTN).

Still, many VoIP providers do not support one important feature of casual telephony systems: Emergency Call Handling (ECH). Skype explicitly refuses the handling of ECHs, and several VoIP providers as well. However, Emergency Call Handling is mandatory feature of telephony services of the future (see next Section). Solutions for ECH based on the P2P paradigm have the potential of great impact. Firstly, P2P solutions scale with the number of participants (which is critical in emergency situations like the attacks at 9/11), and secondly (P2P) overlay networks can be applied on vast set of IP-based networks.

In this paper we present a P2P-based solution for Emergency Call Handling in VoIP networks: ECHoP2P. The solution can be applied due to the characteristics of P2P overlays to any IP-enabled network, like current and next generation telephony networks.

The structure of the paper is as follows: first we describe in Section 1.1 legal requirements on ECH in VoIP networks in the EU, USA and Japan. This overview is followed by a summary of the technical requirements. In Section 2 we present our solution ECHoP2P, which fulfills the technical requirements. Further we discuss related work to our solution. Section 3 shows the comprehensive evaluation of ECHoP2P. And finally we present a conclusion and a summary of our contributions in Section 4.

1.1 Legal Requirements

Regulations on ECH for Internet telephony providers are increasing in the world. Therefore, the support of emergency calls becomes mandatory for providers not only from the ethical but also from the legal point of view. We present a short overview on the ECH regulation approaches in the U.S., European Union in Japan in order to derive the technical requirements in Subsection 1.2.

1.1.1 United States of America

In the U.S. the phone number 911 is used nation wide for any kind of emergency calls. Calling 911 connects the caller with the Public Safety Answering Point (PSAP), which dispatches then the call to an appropriate local fire, police or medical station. In 2005 the Federal Communications Commission (FCC), which is responsible for national and international communications in the U.S., released the *First Report and Order and Notice of Proposed Rulemaking* [3]. This report defines requirements for Enhanced 911 (E911) for IP-enabled Service Providers for the U.S. as a result of life-critical cases [4] [5] in which VoIP customers could not reach 911 and died.

Following requirements were defined in the FCC Order and are valid since 2005:

- (*RU1*) The EC has to be routed the appropriate PSAP based on the caller's location, using Selective Router (SR) (for guaranteed QoS).
- (*RU2*) The call must provide the caller's number (Automatic Numbering Identification ANI) and location (Automatic Location Identification ALI), in the case that the PSAP is able to receive and process the ANI and ALI.
- (*RU3*) The location of the caller must be obtained by the VoIP Service Providers (VSPs) before service initiation.
- (*RU4*) Performance bounds in terms of delay for call establishment.

1.1.2 European Union

In 2002, the European Parliament and the Council of the European Union adopted the European Union Regulatory Framework for Electric Communication [6]. The framework contains a general and four specific guide lines on communication, being respectively the Universal Service, Data Privacy, Authorization and Access Directive.

ECs are considered as an universal service, therefore the corresponding requirements are defined in the Universal Services Directive [7], which is in effect since 2003.

This Directive only addresses Publicly Available Telephone Services (PATS) but no Electronic Communication Service (ECS) providers, who may be offering telephony services. Consequently obligations for VoIP Service Providers (VSP) under the Universal Directive and the EU Regulatory Framework depend on whether the service provided is regarded as PATS or ECS.

In 2004, a consultation and information document on the Treatment of VoIP under the EU Regulatory Framework [8] was published. Based on the consultation results, the European Commission did not state in depth guiding principles on VoIP. Nevertheless, in 2005, the Commission strongly recommended Member States to establish regulations to facilitate the development of new services and markets (e.g. VoIP). Ther0efore, National Authorities should establish their own requirements regarding IP telephony.

Currently in 17 European countries exist legal requirements on VoIP providers for access to emergency services. The established legal requirements include [9]:

- (*RE1*) Routing an EC to an appropriate emergency response center
- (*RE2*) Delivering a call with an according Calling Line Identification (CLI)
- (*RE3*) Providing a call back possibility for the emergency response team
- (*RE4*) Providing a possibility to identify the caller (e.g. via the CLI)
- (*RE5*) Providing the location information of the caller

National legal requirements vary among countries [9] as Table 1 shows, where the numbers correspond to the above listed requirements. Requirements, such as the call routing to an appropriate emergency station, are mandatory as long as they are technically feasible.

Country	EU Req.	Country	EU Req.
Austria	1,2,4,5	Czech Rep.	1,2,4,5
Denmark	1,5	Estonia	2,3,4,5
Finland	1,2,3,4,5	France	1,5
Germany	1	Hungary	2,4,5
Iceland	1	Ireland	1 ,2,5
Norway	1,2,4,5	Poland	1,2,4,5
Portugal	1,2,3,4	Romania	1,2
Sweden	1,2,5	Switzerland	1,2,3,4,5
UK	2,3,5		

Table 1. European Union: National legal requirements on ECH for VoIP providers.

Furthermore the U.S. and EU state requirements on the latencies occurring in an Emergency Call in the PSTNs [10] and UMTS/GSM [11]. The maximum latency to contact the proper emergency station must not last longer than 10s (*RE6*) and the maximum latency for the first estimation of the caller's location must not last longer than 7s (*RE7*).

Concerning standardization, according to the EU Regulatory Framework (Article 17) [6], the Commission shall provide a list of standards or specifications in order to promote their implementation in the Member States. In 2003, the European Telecommunications Standards Institute (ETSI) group EMTEL released a special report on requirements for ECH [12] but the report was reopened in April 2006 in order to include requirements for VoIP and SIP based emergency and location services. Concludingly, law on ECH over VoIP is still in progress, but legal requirements stated are similar to the requirements in the U.S.

1.1.3 Japan

The emergency call numbers in Japan are 110 for police, 118 for coast guard and 119 for fire and ambulance services. Dialing one of these emergency numbers connects the call to an emergency call acceptance organization

(ECAO), which routes the call to the appropriate emergency agency within its district.

In March 2004, the Japan Ministry of Internal Affairs and Communications (MIC) created the Committee for the Advancement of Emergency Message Systems (CAEMS) with the mission of establishing requirements for emergency call handling in VoIP. In the CAEMS draft of 2005 [13], the proposal on IP telephony requirements for emergency messages includes:

- *(RJ1)* VSPs must support 110, 118 and 1119 emergency call services ensuring that the emergency call will be routed to the appropriate ECAO, even under network congestion.
- *(RJ2)* Only the emergency call center must be able to finish the call.
- *(RJ3)* A *reversing call* functionality must be supported, in such a way that the ECAO is able to continue the communication with the caller, even if the caller terminates the call, while the connection is being kept.
- *(RJ4)* CLI must be provided (for call back purposes), even if the caller set the Calling Line Identification Restriction (CLIR) option.
- *(RJ5)* VSP identification must be presented to the emergency dispatchers. ECAOs use this information to obtain subscriber's information.
- *(RJ6)* Caller's location information must be supplied when the ECAO receives the emergency call as well as when the ECAO asks for subscriber's information from the VSP.

Japan's legal requirements on ECH are similar to that of the U.S. and the EU. However, they expand the view on use cases for ECH. With this knowledge we summarize the technical requirements in the following subsection.

1.2 Technical Requirements

In order to discuss possible solutions for efficient, scalable ECH, we briefly present the obtained requirements:

- ***(Req1)*** Provision of the caller's number for call backs and identification *(RU2)*, *(RE2)*, *(RJ4)*
- ***(Req2)*** (Fast) provision of the caller's geographical position *(RU3)*, *(RE5)*, *(RE7)*, *(RJ6)*
- ***(Req3)*** Identification of the calling person *(RE4)*, *(RJ5)*
- ***(Req4)*** Provision of call back opportunities and call upkeeping *(RE3)*, *(RJ2)*, *(RJ3)*
- ***(Req5)*** Dispatching the call to emergency station responsible for the caller's location *(RU1)*, *(RE1)*, *(RJ1)*
- ***(Req6)*** Highest delay priority for emergency calls: low delay bounds *(RU4)* *(RE6)*
- ***(Req7)*** Provision of stable communication even under network congestion *(RJ1)*

We focus in the following only on the requirements on ECH which are relevant to consider in creating a network-based ECH architecture, i.e. on requirements ***(Req5)***, ***(Req6)*** and ***(Req7)***.

We ignore requirements ***(Req1)***, ***(Req2)*** and ***(Req3)***, because they define the set of information which has to be known about a caller: it's network identifier, it's personal information and it's geographical position. In the following we assume that each participating communication node knows these information.

Requirement ***(Req4)*** is of low interest for research on networks, as it depends on the implementation of an ECH systems who is allowed to end emergency calls.

Interesting challenges for research on network architectures are defined by requirements ***(Req5)***, ***(Req6)*** and ***(Req7)***: Contacting the responsible (or closest) emergency station and provision of QoS in terms of low delay and no loss for Emergency Calls. In this paper we present our solution ECHoP2P that fulfills these requirements, further we discuss related work and present the evaluation of ECHoP2P.

2 ECHoP2P: Scalable P2P-based ECH

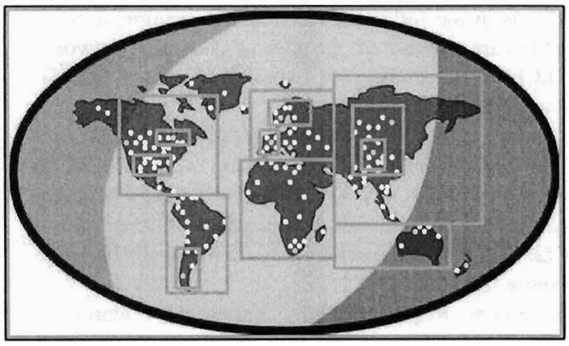
2.1 Using the Peer-to-Peer Paradigm

In order to establish a connection to the appropriate emergency station (ES), the corresponding ES in the network first has to be identified. This information can either be stored centrally in a client/server system, or distributed using the P2P paradigm. The drawback of client/server-based emergency system could be observed during the 9/11 attacks in the U.S. The emergency systems were overwhelmed with the wast amount of emergency calls occurring after the attacks, only a few got through [14]. Client/server systems do not scale with the number of participants and requests. P2P systems are scalable by distributing the load on all participating peers [15]. Scalability and availability are key components for emergency and first response systems.

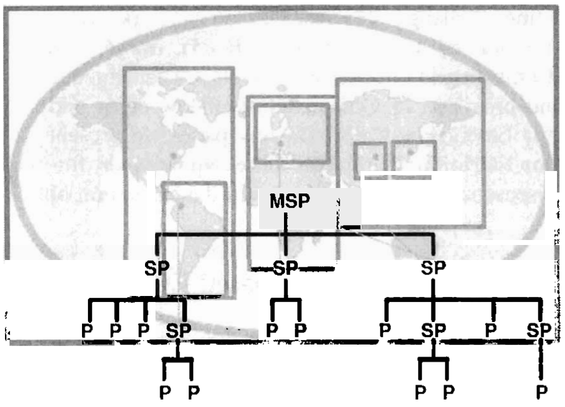
Furthermore, P2P systems have been applied to mobile wireless networks based on GPRS [16] and UMTS [17]. They are suitable to overcome the traditional separation of these networks by adopting overlay networks to all kind of IP-enabled networks. With this, an emergency call system based on the P2P paradigm can be applied on any IP-enabled network. For these reasons we use the P2P approach as underlying network architecture.

2.2 Finding the corresponding Emergency Station

One of the main requirements for ECH is the dispatching of the call to the appropriate ES ***(Req5)***. Two kind of



(a) Zone Assignment in Globase.KOM



(b) Tree Structure of Globase.KOM

Figure 1. Architecture of Globase.KOM: Zones and Tree Structure

applications exist: Either the corresponding ES is defined by its distance to the caller (closest ES) or by predefined responsibility areas. Any distributed architecture for ECH has to provide these two functions. The search for ALL emergency station (or more generally: peers which fulfill specific criteria) in a specific area is challenging. We present Globase.KOM, our solution for location-based search in P2P systems. Globase.KOM is a superpeer-based overlay forming a tree enhanced with interconnections (see Figure 1(b)). The world projection is divided in rectangular, non-overlapping zones (Figure 1(a)). Each zone is assigned to a superpeer which keeps overlay/underlay contact addresses to all peers in that zone and is located inside of the zone. Superpeers form a tree where peer A is called the parent of peer B when B's zone is inside A's zone.

More details about the architecture and protocol of Globase.KOM can be found in [18]. Here we focus on the relevant new operations that Globase.KOM provides - SOS area search and SOS responsibility search.

SOS Area Search In this operation, the caller peer sends an SOS_SEARCH message with the purpose to find a list with the contact information of the close emergency stations including the closest one. The caller peer first calculates the distance to the closest border of the zone it belongs to. This is possible by using the ID of the parent superpeer, which contains a vector representation of the zone bounds [18]. Then, the peer sends a FIND_CLOSEST message to its parent superpeer, containing the calculated distance to the closest border of the zone. If there are some peers in the area around the initiator, with the radius of the given distance (to the closest border), the superpeer calculates the closest and includes it in a FIND_CLOSEST_RESULT message. Otherwise, it sends back FIND_CLOSEST_NEXT message which includes the address of its parent superpeer. The peer again calculates the closest border of the zone of the retrieved superpeer, expands the search radius, and sends the newly formed FIND_CLOSEST message to the retrieved superpeer. The steps are then repeated iteratively until the peer receives a FIND_CLOSEST_RESULT message containing the contact of the closest peer, corresponding to the closest emergency station.

SOS Responsibility Search In this operation, the caller peer sends an SOS_RESPONSIBILITY_SEARCH message to its father in order to find the contact information of the emergency station, which is responsible the SOS caller's position. This operation works under the assumption that every emergency station has its own coverage area. This coverage area is considered rectangular for simplicity in the scenario set up, see Figure 2. However, theoretically there is no restriction to the shape of the coverage area. Superpeers know the emergency stations within their domains, specifically, their geographical position as well as their coverage area. Contacted superpeers answer to a SOS Responsibility Search message, either by sending back the contact information of the emergency station covering the SOS caller's position or redirecting the search message to their children superpeers. If the caller receives no answer within a given *timeout (TO)*, the caller sends a SOS_RESPONSIBILITY_SEARCH message to the Main Super Peer in the tree. In this case, routing to the superpeer which has the emergency station inside of its area is done similarly to the lookup operation of Globase.KOM [18].

SOS Responsibility Search Extended As an extension to the SOS Responsibility Search, this operation not only finds the responsible Emergency Station, but also provides a list of more Emergency Stations. For this, each superpeer, which receives a SOS_RESPONSIBILITY_SEARCH either answers either with the contact information of the ES responsible for the caller's position, or with the contact information of the ES closest to the caller's position in the superpeer's zone. Having a list of ESs is useful in certain catastrophe scenarios.

In order to minimize the load on the Main Super Peer in Globase.KOM, we introduce an optimization: *Redirect to*

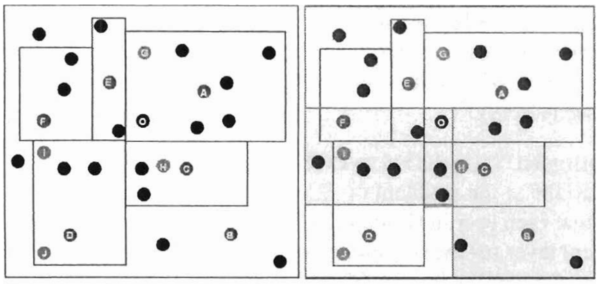


Figure 2. Emerg. Stations Coverage Areas

Father (R2F). In case of a failed search, the SOS Responsibility Search message is not directly sent to the Main Super Peer, but first to the grandfather of the calling peer in the tree. This step is motivated by the idea, that the responsible ES is expected to be in the near of the calling peer, i.e. under the domain of its father or grandfather. However, in order to limit the number of messages, SOS Responsibility Search messages have a *Time to Live (TTL)* field. In the evaluation (Section 3) we show the quality of the proposed extension to Globase.KOM [18]: SOS Area Search and SOS Responsibility Search (Extended). Further we investigate the effects of *R2F* and *TTL*.

The described solution and its extension with SOS responsibility search and SOS area search, fulfills the requirement (***Req5***).

So far, location-based search in P2P networks is mainly approached by re-using existing structured overlays that are used to provide efficient one dimensional lookups [19] [20]. The linearization of two-dimensional map projections is achieved using different space filling curves. The suitability of different space-filling curves is discussed in [21]. The focus of [19] in developing Prefix Hash Trees (PHTs) was to meet the needs of an end-user positioning system, without modifying the underlying DHT. It is able to perform two dimensional geographical range queries by applying a Z-curve linearization of the 2D space. All approaches with space-filling curves suffer from not matching the geographical distance with the distance in the overlay ID space. This results in inefficient query replies which introduce additional delay into the communication. Another important point is that most of these are using DHTs which do not provide complete retrievability of a search request. In Globase.KOM geographical an overlay distances match and fully retrievable location-based search is provided.

2.3 Improved Quality-of-Service for Emergency Calls

The requirements (***Req6***) and (***Req7***) are stating demand on the quality of service provided for the emergency calls during the call establishment and maintenance. The call establishment is of high importance, as here the delay and loss criteria are critical. Imagine a person calling the police over a VoIP phone and his call message is dropped in the network due to congestion based on file sharing traffic. Emergency calls have high priorities for the user, both in terms of delay and in terms of loss. In IP networks these priorities are more relevant, as cross traffic may delay or congest the network, which is not the case in ATM networks. Priorities for delay and loss have to be mapped to the emergency call handling architecture. In the following we discuss our solution for QoS-enabled call establishment over Globase.KOM.

In order to provide distinguished quality of service for emergency call messages, each peer is assumed to have a message queue for overlay messages. In this messages are cached when no upload bandwidth is available. This is a valid assumption as current Internet connection technologies offer usually a higher download capacity than upload capacity. The message queue is located below the overlay layer but above the network layer. Messages that a peer wants to send are first cached in the message queue and from this messages are taken when upload bandwidth is available again.

The order in which the messages are picked from the queue and sent depends on the scheduling mechanism that is applied. Which messages is picked influences directly the delay of the message class. We investigated in [22] the adoptability of scheduling mechanisms from the network layer on P2P overlays. Therefore we surveyed on 21 scheduling mechanisms and identified 2 classes of scheduling mechanisms that are relevant in this context: flow-based and stateless. Before briefly describing these two classes, we shortly introduce the concept of Active Queue Management (AQM): in case of queue congestion, messages has to be dropped out of the queue. Which message to drop an when to drop is determined by the applied AQM mechanism. The chosen AQM mechanism influences directly the loss ratio of each message class. We researched on the applicability of AQM mechanisms for overlay traffic and proposed a taxonomy in [23]. As a result we differentiate between flow-based and stateless solutions, too.

Flow-based scheduling mechanisms allocated to each flow, identified by a source-destination pair, a fair amount of available bandwidth. This means that all flows passing the system receive an equal share of upload bandwidth. However, in context of EC establishment, we do not have flows. An EC is set up by finding the corresponding emergency station using Globase.KOM and afterwards contacting this ES directly, from peer to peer. We cannot identify in this short time period of call establishment a source-destination pair, for which we can know in advance, that more messages for this flow will come. Even more, an emergency call setup is very short termed, it does not make sense to store additional flow information, when the flow consists only of a few messages.

Sariou et al. measured P2P systems [24] and talk in this context of *mice flows* in contrast to *elephant flows*, which describe long lasting flows producing significant traffic. In [25] the non-existence of long-lasting flows in the overlay Kademlia [26] has been shown, the authors showed that each peer (in a network with 10,000 peers) has in average 500-1000 contacts, but with only 2 messages per contact in maximum. As conclusion we state that flow-based routing algorithms cannot be applied for provision of QoS for Emergency Calls in P2P systems.

The second type of scheduling mechanisms are stateless. They do not store any information about flows or observations. Stateless schedulers and AQM mechanisms decide only based on current information, e.g. the status of the queue, message characteristics, and so on. For our solution we use a stateless scheduler and AQM mechanism.

2.3.1 Our Solution: HiPNOS.KOM

In order to fulfill (***Req6***) and (***Req7***) we apply a priority based scheduler and AQM mechanism: HiPNOS.KOM (Highest Priority First, No Starvation) [25]. Here we summarize our investigations on overlay bandwidth management, which we presented first in [25]. Afterwards we present how it can be applied to the ECH scenario using Globase.KOM.

For ECH we propose to use two separate priorities (for delay and loss), which is directly stored in each message. This is done to provide each peer on the path of the message information how to handle the message. The priorities are described by 1 byte each, with a value range from -128 to 127, a high value represents a high priority. HiPNOS.KOM is located directly below the overlay and above the network layer. Each message is first cached in a message queue. While including a message in the queue the AQM part of HiPNOS.KOM is used.

AQM with HiPNOS.KOM For the message queue a certain static queue limit is known. Once the number of messages exceeds this threshold (checked while inserting a new message) a message out of the queue is dropped. The appropriate message is chosen by comparing the loss priorities of each message in the queue. The message with the lowest loss priority in the queue is dropped. With this we make sure that the message with the least importance is dropped and more relevant messages stay in the queue.

Scheduling with HiPNOS.KOM Once the message is added to the cache, it is checked whether upload bandwidth is available or not. Whenever bandwidth is available, the message with the highest priority regarding latency is picked from the queue and transmitted (HiP). By changing the order in which the messages arrive and leave the system, messages with a higher delay priority value leave the system faster and are not delayed by rather less important messages. In order to avoid starvation of messages with low delay priority but high loss priority in the system, the delay priority of each message in the system is periodically increased (NOS).

Adopting HiPNOS.KOM to ECH In order to apply HiPNOS.KOM to the problem of ECH in P2P-networks, consider that each peer in Globase.KOM has a bandwidth management layer for overlay message. Furthermore each message in the overlay has predefined priorities. Whereas the priorities can be assigned dynamically based on the current state of the network, this is out of scope of this paper, so we stick to static priorities. Emergency Calls have both high delay and loss priorities. Second, normal operations (location-based search and lookup) have mediocre priorities and maintenance messages are categorized in low priority classes. With this we want to provide for each EC best quality of service, as in any case EC messages are processed faster and are not dropped, if less important messages are in the queue as well.

Related Work on Overlay Bandwidth Management Overlay bandwidth management has not gained significant attention until now in P2P research. Hoßfeld et al. investigate P2P applications in mobile wireless networks based on GPRS [16] and UMTS [17]. Their focus is own GPRS and UMTS issues, less on P2P. Further bandwidth management for P2P overlay streams has been investigated in [27], [28], [29], and [30]. They assume long lasting multimedia streams, whereas we focus on the QoS for Emergency Call establishment, where no flows exist. Only GIA proposed by [31] considers providing QoS for different overlay messages in an enhanced Gnutella overlay. However, in GIA peers just regulate the rate of incoming request by periodically sending tokens to neighboring nodes. For one processed request, one token must be delivered. By the token generation rate each peer regulates its incoming traffic. In contrast to this, HiPNOS.KOM focuses on the outgoing traffic and provides QoS for different message classes.

2.4 Summary on ECHoP2P

In conclusion we propose to use Globase.KOM, an P2P overlay for location based search, for finding the closest emergency station of a calling peer. Further we presented a function of Globase.KOM with which a calling peer can find the emergency service station that is responsible for its location. With these to approaches the requirement of finding the correspondent emergency station, (***Req5***), is fulfilled. Furthermore, HiPNOS.KOM provides better quality of service for messages for the establishment of the emergency calls, by decreasing the quality of service for less important messages. In the next section we present the evaluation of our solution.

3 Evaluation

For evaluation we chose simulation, as simulations show effects of large-scale distributed systems. In this section we describe first the simulation platform we used, then describe the simulation setup and scenario, and finally we present the evaluation results.

3.1 Evaluation Platform

Numerous P2P simulators exist in P2P research community. We chose PeerfactSim.KOM [32] [33], a P2P simulator, as it focuses on inter-dependencies between various layers in a P2P systems. With this we can apply HiPNOS.KOM overlay independent. Other simulators are mainly focused on isolated overlay evaluation.

3.2 Scenario and Simulation Setup

In order to evaluate the performance of the proposed SOS search an QoS operations, a simulation scenario was configured based on statistics for 911 calls in U.S. [34], the distribution of Emergency Communications Districts (ECD) in the state of Alabama [35] and the population density in Alabama [36]. The latter has been used for describing the peer distribution in the simulator. We present in Figure 3 how we used this information.

3.3 Evaluation Results

According to Figure 4(a), the average time required to obtain the first result for an SOS Responsibility Search Extended is 43% less than the operation duration needed for a SOS Responsibility Search and 21% less than for an SOS Area Search. This behavior is expected because during an SOS Responsibility Search Extended, a contacted superpeer sends to the caller either the contact information of the responsible station or the information of the closest found emergency station.

Also the average number of contacted peers per operation has an influence on the performance of the SOS search algorithms; as shown in Figure 4(b), the average number of peers contacted during a successful SOS Responsibility Search Extended is twice higher than in an SOS Area Search and three times higher than in an SOS Responsibility Search. These results demonstrate that the more peers are contacted; the more likely is to obtain a better operation response time. Nevertheless, contacting more peers implies an increase in the amount of SOS search messages on the network, a trade-off between operation duration and generated traffic is necessary. In this situation, the SOS Are Search operation offers a middle average operation response time and number of contacted peers in comparison to the two versions of the SOS Responsibility Search.

Regarding the distance between the caller and the found emergency station during an SOS Search, Figure 4(c) shows that from the received results, the average minimum distance to the obtained station using SOS Area Search is 28% and 17% smaller than for SOS Responsibility Search and SOS Responsibility Search Extended respectively. These results show that in the simulated scenario the responsible station for the caller's location is not necessarily the closest one. The figures measure the distance in pixels related to resolution of the bitmap maps that are used for simulation setup. This value is directly proportional to the geographical distance.

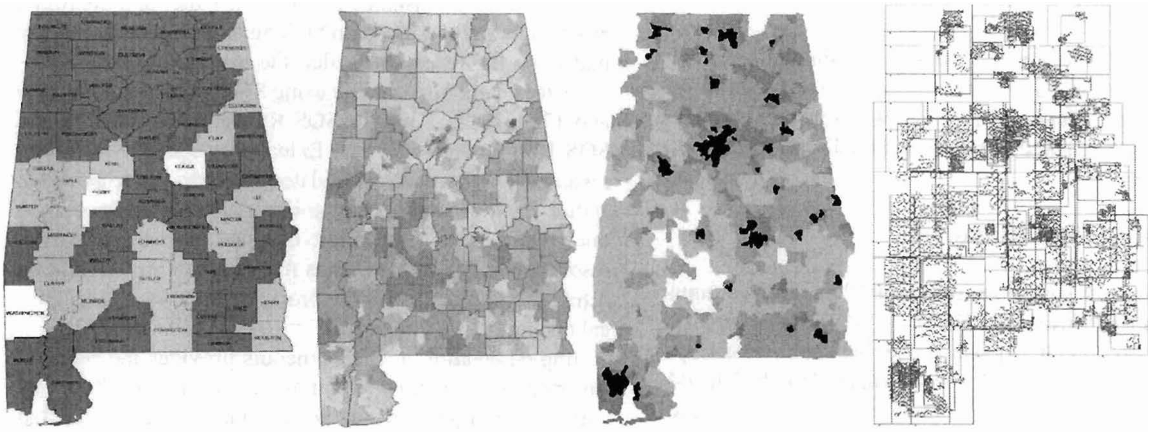
Implementation of SOS timeouts provides the successful operation percentages summarized in Figure 5(a). The value of the timeout has to be specified in such a way that the initial search has an operation time interval great enough to find possible results and consequently. Queries to the Main Super Peers are only delivered after the timeout in case of failure situations describes above. According to Figure 4(a), the maximum operation duration required to obtain a search result is about 150ms, therefore for simulating operation timeouts we defined the minimum timeout at 300ms, the maximum considered timeout was 1s because as Figure 5(a) shows, the value of the timeout impacts the average operation response time for successful searches.

The quantity of SOS search messages increments considerably by activating the redirection to father as Figure 5(b) shows. However, with using redirection the response time reduces to the half (third) for SOS Responsibility Search (Extended).

With the aim to reduce the SOS related traffic we implemented a SOS search time to live in such a way that SOS messages older than the specified time to live are not processed. Figure 5(c) shows that for SOS Responsibility Search Extended the amount of SOS search messages is reduced by 46%, for SOS Responsibility Search by 19.4% and for SOS Area Search by slightly 4%. This reduction of the SOS traffic generated does not change the percentage of successful operations.

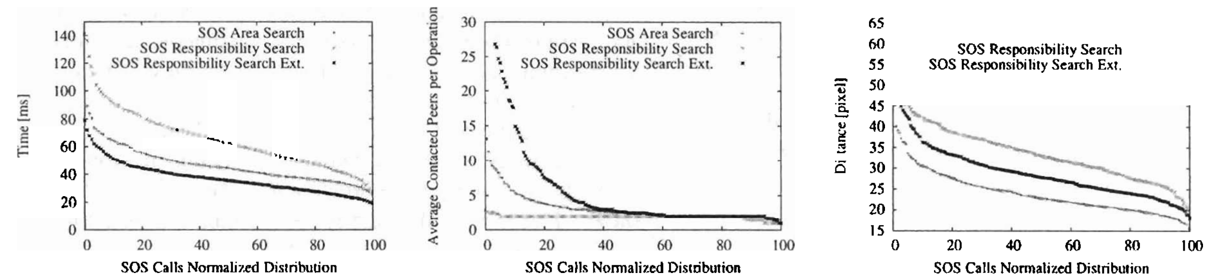
3.4 Evaluation Conclusion

As the conclusion of the evaluation we discuss the identified tradeoffs. The 3 different SOS Search algorithms have specific characteristics, presented in Table 2, which suit them for different application areas. SOS Area Search is suited for application areas, in which the closest peer with specific characteristics (being ES) has to be found. SOS Responsibility Search is to be used in environments with low available bandwidth to find the peer in the system, which is linked (e.g. by responsibility) to the querying peer. SOS Jurisdiction Search Extended provides a list of various peers fulfilling a specific criteria very fast, but with high traffic overhead costs.



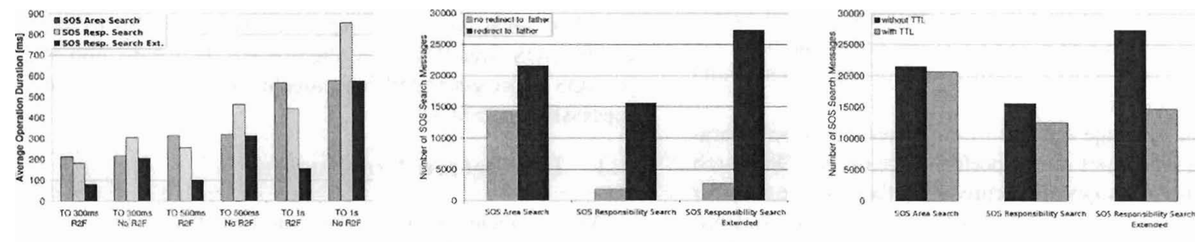
(a) Alabama: Respons. Areas [37] (b) Alabama: Pop. Density [36] (c) Setup: Peer Loc. Probability (d) Snapshot of Globase.KOM

Figure 3. Simulated Scenario: Alabama's population density [36] and ECH responsibility areas [37] as basis for the peer locations in the simulations



(a) Average response time for successful operation (b) Average contacted peers per operation (c) Average distance between caller and found ES

Figure 4. Response time and contacted peers for successful SOS operation and average distance between caller and found ES



(a) Effects of timeouts on response time (b) Effect of redirection to father on overhead (c) Effect of TTL on overhead

Figure 5. Effects of timeouts, redirection to father and TTL on response time and overhead

The usage of timeouts leads to decreased traffic overhead, but also to a decreased size of the retrieved ES list. The *redirection to father* option shifts load from the Main Super Peer to casual superpeers in the tree by extending the search radius in the first attempt.

4 Conclusion

For VoIP providers Emergency Call Handling (ECH) will soon be or already is mandatory. We investigated the legal and technical requirements for ECH of several countries. According to the well defined requirements we presented ECHoP2P, a solution for Emergency Call Handling

SOS Search	Resp. time	Traffic costs	Distance
AS (closest ES)	medium	medium	good
RS (respons. ES)	bad	good	bad
RSE (list of ESs)	good	bad	medium

Table 2. Tradeoffs for the different SOS Search Operations

using a P2P based architecture. We adopted HiPNOS.KOM [25], a overlay bandwidth management mechanism to the requirements of ECH. With this, Emergency Calls are processed with higher performance than casual overlay messages. Further we extended Globase.KOM [18] with 3 new functions (SOS Area Search and SOS Responsibility Search (Extended)). The given solution fulfills the requirements on ECH and can be used for several application areas based on location based search. Besides the Emergency Call scenario, the presented solution can be used to identify geographically closest objects to a querying peer and to find objects/peers with specific characteristics in the geographical neighborhood of the querying peer. We evaluated ECHoP2P thoroughly and identified tradeoffs between traffic overhead, response time and distance to the found Emergency Stations. Further we introduced several optimization parameters: *redirect to father*, *timeouts* and *time to live*. With these parameters the tradeoff between traffic overhead and response time can be adjusted.

Concludingly, ECHoP2P provides a thoroughly evaluated solution for P2P-based Emergency Call Handling in specific and location based applications in general.

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