

A Proposed P2PSIP Framework For Extreme Emergency Situations in a Wireless Environment

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ABSTRACT

The Session Initiation Protocol (SIP) has been widely regarded as one of the most popular protocols for providing real-time multimedia services. However, in wireless ad hoc networks where no infrastructure is present but communication is required, such as in many extreme emergency scenarios, the SIP central server model becomes a central point of failure. The nature of mobile ad hoc networks makes them suitable to be utilized in the context of an emergency for various rescue teams. This requires the design of an overlay architecture such as Peer to Peer SIP, above the transport layer of the networks, to provide services for delay sensitive applications such as VoIP and Video. In this paper we propose a framework for handling the P2PSIP overlay. A hybrid structured and unstructured P2PSIP overlay is defined using the literature popular DHT-Based CHORD and the Low diameter algorithms. Additionally, a novel cross-layer design is proposed to provide failover mechanisms that can address the key research challenges surrounding availability and reliability within mobile ad hoc networks for supporting emergency services in extreme catastrophic events.

General Terms

Design

Keywords

IP-based emergency infrastructures, P2PSIP, Cross-layer, Wireless Networks

1. INTRODUCTION

In order to facilitate real-time multimedia services in Next Generation Networks the Session Initiation Protocol (SIP) has been proposed and widely deployed in its client/server mode. SIP [1] defines a number of entities such as registrar and proxy servers to perform registering, lookups, and routing SIP messages to their appropriate destinations of SIP users anywhere/anytime, using a DNS based system within SIP network.

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Mobimedia '09, September 7–9, 2009, London, UK
2009 ICST 978-963-9799-62-2/00/0004...\$5.00.

This server-centric approach has proven quite effective, but has become the single point of failure in situations where reliability and availability is of highest importance. To be able to provide SIP services in mobile Ad-hoc or ephemeral networks for extreme emergency situation requires a server-less solution that does not entail an elaborate setup or configuration such as a peer to peer model of intelligent nodes. It could help leverage the classical client-server systems by providing continuity of service in the event of server failure [2]. The Peer to Peer SIP (P2PSIP) model will allow the creation and maintenance of a connected network of nodes, which have the ability to store and locate overlay resources without any external intervention.

In this paper, we outline in detail a P2PSIP hybrid architecture that enables decentralised SIP communication and we define a novel architecture that can be used to develop failover mechanisms in a wireless P2PSIP environment. In section 2 we discuss related works presenting the design of P2PSIP networks in fixed and wireless networks. Section 3 discusses the details of the DHT-based CHORD and low diameter algorithms, the requirements for an extreme emergency P2P overlay and the details of the P2PSIP hybrid architecture. Section 4 defines the novel P2PSIP cross layer interface called the budget factor for wireless environments in extreme emergency situations that can be used to develop failover mechanisms. Section 5 concludes the paper.

2. BACKGROUND and RELATED WORK

An overlay network is a computer network which is built on top of another network. Nodes in the overlay can be thought of as being connected by virtual or logical links, each of which corresponds to a path, perhaps through many physical links, in the underlying network. Peer-to-Peer (P2P) overlay networks are distributed in nature, without any hierarchical organization or centralized control.[3] These systems are inherently scalable and reliable because of the lack of a single point of failure which is caused by central servers.

Structured P2P topologies are usually constructed using *distributed hashing table-DHT* techniques, for example Chord. There are also some unstructured P2P topologies that make use of a low-diameter P2P network with $O(\log N)$ lookup. The main idea is to construct a P2P random graph with low diameter $O(\log N)$ and limited node degree under a probabilistic model of node arrival and departure[4]. The property of low diameter can guarantee short query path length and low control message overhead.

In order to setup, maintain and tear down multimedia communication between the ad hoc nodes, there must be discovery of the host at which a given user can be reached [5].

A P2PSIP Overlay consists of one or more nodes called Peers. Collectively, the nodes in the overlay provide a distributed mechanism for mapping names to overlay locations. This provides for the mapping of Addresses of Record (AoRs) to Contact URIs, thereby providing the "location server" function of [RFC3261]. An Overlay also provides a transport function by which SIP messages can be transported between any two nodes in the overlay. The peers in the overlay collectively run a distributed database algorithm. This distributed database algorithm allows data to be stored on peers and retrieved in an efficient manner. The ad hoc nodes (peers) may be considered as the "infrastructure" for these networks such as in natural or manmade disasters. A key characteristic of the P2PSIP architecture is that a separate layer, independent of SIP, provides the P2P overlay functions and SIP is an application using the services of the layer.

P2PSIP architecture can be achieved in two major ways: P2P over SIP and SIP using P2P. In both [6] and [7] there is reference to the use of variants of the P2P over SIP architecture in order to establish P2PSIP communication in both mobile and fixed environments. Using the chord DHT implementation, the authors were able to show that the SN (super nodes) can be used to form the logical Chord ring and manage the routing and lookups within the P2PSIP overlay while their associated ON(ordinary nodes) can be excluded from managing the DHT since they do not have the capabilities [7]. Bryan et al [8] demonstrated the SOSIMPLE mechanism with the SIP using P2P architecture. They included a structured CHORD like ring for efficient lookups and resource locations. Also, a collocation of a SIP UA with a Peer or a client probably residing in a mobile client demonstrated P2PSIP in a mobile environment using a Chord-based DHT P2P network and relay servers [6].

In addition, a new IETF working group [9] has been formed with the task of developing P2PSIP protocols for the decentralization of SIP. They have to date defined ReLOAD [10], which is mainly targeted for the fixed environments and includes NAT and firewall transversal. The authors defined a protocol stack that can make use of any DHT or non DHT-based algorithms, but used the CHORD algorithm as a must implement algorithm to facilitate interoperability. In [11] the authors made use of a DHT-plugin at the user agent in order to provide multiple overlay participation by a peer node. [12] considered the large overhead caused by maintaining the DHT CHORD under churn, which is inherent within wireless ad hoc networks, and proposed an unstructured P2PSIP (UP2PSIP) architecture that uses a low diameter algorithm to reach its buddies via one hop. The UP2PSIP approach maintains very good property of low latency and maintenance overhead in both fixed and mobile environments compared to the CHORD algorithm.

Within the wireless network scenario the authors of [13] proposed an integration of the SIP services with a cluster based ad hoc routing and subsequent enhancements such as the IEEE 802.11 MAC Layer to support them.

3. SYSTEM DESIGN

3.1 Chord and Low Diameter Protocols

The most common implementation of the DHT based P2P overlay at present is the Chord model due to its low latency

lookup. Chord [15] is a decentralized P2P lookup service that stores key/value pairs for distributed data items. Given a key, the node responsible for storing the key's value can be determined using a hash function that assigns an identifier to each node and to each key (by hashing the node's IP address and the key). Each key k is stored on the first node whose identifier id is equal or follows k in the identifier space. In Chord, active nodes will form a connected Ring P2P topology under ideal case. Each node maintains a routing table with information for only about $O(\log N)$ nodes. In fact, Chord is similar to binary search, where the searching space will be reduced by half after a search/routing-hop. So the number of nodes that must be contacted to resolve a query in a N -node network is $O(\log N)$. In literature, there are some other variants of Chord, namely Viceroy and Multi-Ring.

Considering the low diameter algorithm with guaranteed short query path length and low control message overhead. Each node keeps some random connectivity, so they can overcome some random attacks. The protocol works as follows: the **host server** maintains a cache of K nodes, where K is a constant. The host server is reachable by all nodes at all times; however, it need not know of the topology of the network at any time, or even the identities of all nodes currently on the network. A newly arrived node first contacts the host server, which gives it D random nodes from the current cache to connect to, thus become into a d -node. At some point, the protocol may put a d -node into the cache. It stays in the cache until it acquires a total of C connections, at which point it leaves the cache, as a c -node. A c -node might lose connections after it leaves the cache, but its degree is always at least D . This protocol will ensure that the degree (number of neighbors) of all nodes will be in the interval $[D, C+1]$, for two constants D and C . When time t is big enough, the random graph has diameter $O(\log N)$ with high probability [16]. Hence we are guaranteed to have efficient and reliable look-ups within the Peer to Peer network.

3.2 Extreme Emergency P2P Overlay

In order to be an efficient P2P overlay network there must be a good mix of performance, scalability, reliability, usability, and maintenance of the overlay [14]. Any choice of P2P overlay will inherently affect the application that will be used; hence the best choice of overlay is imperative, especially in terms of locating, routing and structuring of the overlay. In terms of a mobile wireless environment, such as an extreme emergency situation with numerous nodes experiencing different levels of network conditions, a very careful choice of P2P overlay is needed to provide the base for the multimedia communications required in an emergency situation. This work aims to propose a hybrid P2P overlay consisting of the DHT based Chord and the Unstructured P2P as a candidate solution to support extreme emergency applications.

3.3 P2PSIP Architecture

The main reason for P2PSIP communication is the need for the decentralization of the single point of failure inherent to legacy SIP communication. It has the ultimate purpose of enabling serverless-based real-time communication, using the SIP protocol with no SIP proxies and registrar servers. The P2P nodes will be responsible for call setup and maintenance. There must be a distributed database used for storage and retrieval of the P2PSIP entities such as Node Id's and User Id's used for call setup, and

maintenance. However, most of the research to date for P2PSIP was done in a fixed environment, and the most popular solution for the P2PSIP implementation is a DHT based Chord system, because of its simple put and get mechanism.

Within a mobile wireless environment, such as in the context of an extreme emergency scenario, the users roam randomly within the wireless networks, and to ensure a stable DHT-based Chord for P2PSIP introduces serious problems. The DHT-based network has significant overhead in maintaining its structure under churn. An unstructured P2P network proposed in [12] is less influenced by the churn property caused by constant node movement and is, hence, more suitable for the mobile environment. Moreover, the unstructured P2PSIP network can be constructed according to the relationships between SIP users and their friends, such as a fire brigade company etc. Each node maintains a buddy list and a neighbour table which can be used to monitor the presence of its friend nodes and to facilitate a well connected and low-diameter P2P network. This design ensures that nodes concentrate on the changes of buddies and neighbours rather than the entire topology, as opposed to the Chord-based P2PSIP.

We chose a hybrid P2PSIP system making use of the positives of the DHT-based CHORD and unstructured P2P architecture/overlay structure. Hence, we have a DHT-Based Chord with Super nodes forming the logical chord ring and ordinary nodes linked in an unstructured manner. The super nodes are responsible for one or more ordinary nodes. The ordinary nodes are interconnected to other ordinary nodes forming an unstructured overlay based on a preset and/or adaptive low diameter buddy list, in addition to its normal updatable neighbour list associated with their individual supernodes.

3.3.1 Super Node Functionality:

- Can be either fixed or mobile nodes with the required network capacity eg. CPU Processing power, bandwidth, etc.
- Forms the backbone logical user lookup and discovery ring
- Maintains the structured part of the overlay
- Responsible for its attached ordinary nodes

3.3.2 Ordinary Node Functionality:

- Can be attached to one or more Super Nodes
- Are attached to each other in a low diameter unstructured fashion using buddy list information
- Has a neighbor list of its attached super node, closely associated buddy ordinary nodes, and their corresponding Super Nodes
- Can be users from the same or different emergency units within the extreme emergency scenario

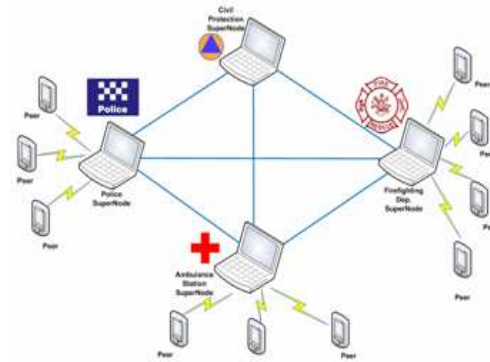


Figure 1. Figure showing hybrid DHT-based CHORD with low diameter unstructured P2P overlay within wireless emergency scenario

4. BUDGET FACTOR INTERFACE

Within an extreme emergency scenario where the nodes that form the mobile ad hoc network are not stable, the churn effect is inherited. As the mobile nodes move around this node mobility can be easily seen at the lower layers, whilst the SIP user mobility is seen within the P2PSIP overlay. The overlay needs to adapt to the changing physical node and SIP user topologies. Any node or user mobility can affect the SIP communication because of their new and probably poor wireless channels. Hence we define and implement an interface for mapping the mobility of the network layer and P2PSIP overlay. This interface will be used as an assist failover mechanism to increase availability and reliability of the real-time SIP communications. This new interface is subsequently described.

- A vertical interface that interacts with the multimedia services, the SIP and P2P overlay, network layers and probably lower layers
- Has its own Budget Factor (BF) Protocols for the node to node interactions.
- This BF is envisioned as a metric calculation which implements upward information flow as a cross layer implementation.
- The budget factor would be proactive and/or reactive to node/SIP communication failure
- The BF layer can trigger a “SIP over” of all or part of the node’s SIP communication for a given time or for all subsequent time of relevant node communication

- In general the BF interface will optimize the P2PSIP multimedia communication eg. Call setup, and maintenance, and supernode selection

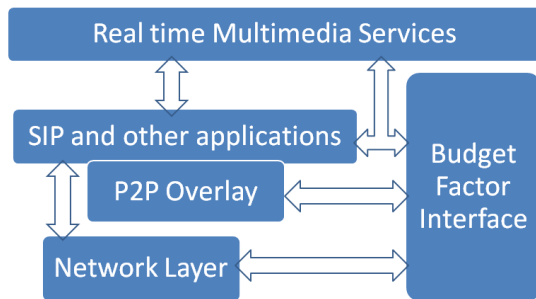


Figure 2. Figure showing novel architecture for developing failover mechanisms in P2PSIP extreme emergency wireless scenarios

The P2P overlay layer implements the Peer to Peer Protocol. The applications access this P2P overlay layer for various overlay-related services. Applications are also free to bypass this layer and access the existing transport layer protocols (e.g., TCP, UDP, etc.) directly. This is a cross-layer mechanism which would be helpful in maintaining the P2PSIP communication given the dynamic nature of the wireless communication channels. The Budget Factor (BF) will optimize the use of the peer processing power and network characteristics that determine the best P2PSIP path for failover mechanisms. It is envisioned as a metric calculation from parameters of node mobility, power, density of ad hoc nodes, available bandwidth and link characteristics which implement upward information flow and would act as a shared database across the layers as a cross layer implementation. This interface will interact with the multimedia services, SIP and P2P overlay, transport/network layers and probable lower layers and has its own BF Protocols for Peer to Peer interactions. The BF protocols between peers would be able to assist them in determining the best available SIP communication path and failover paths when needed.

The need for optimizing failover in this manner can be seen within the context of an extreme emergency situation in which every second counts and the loss of multimedia communication would prove catastrophic. A multimedia application (eg. an emergency operator out in the field on a video call getting directions to exit a hazardous building) can increase its survivability without relying solely on legacy ad hoc routing algorithms. The budget factor would be able to predict node failure, due to failing network conditions/processing power etc. and optimize the P2PSIP multimedia communication with its P2PSIP system knowledge individually/concurrently. The BF layer would trigger a “sip-over” of all or part of the multimedia/communication for a given time or for all subsequent time of relevant node communications.

5. CONCLUSIONS and FUTURE WORK

In this paper, a P2PSIP framework was proposed for extreme emergency situations in wireless environments. The main idea behind the proposed framework is to optimize the availability and reliability of the P2PSIP communication with the design of a hybrid P2P overlay algorithm and a novel cross-layer Budget factor interface used to interface with the lower and upper layers of the protocol stack.

We plan to define the budget factor metric calculation and the corresponding node to node interaction protocols. We are also going to perform simulation experiments to validate the P2PSIP hybrid architecture. Characterization of the user mobility, as it relates to node mobility, will also be considered in the face of wireless network churn considerations of node/user joining and leaving effects. In addition, the BF Layer Interface design with mobile user mapped to its mobile nodes, which in turn are mapped to the P2PSIP overlay, will be an optimal enhancement.

6. ACKNOWLEDGMENTS

The authors wish to acknowledge the support of the ICT European Research Programme and all the partners involved in the PEACE project: PDMF&C, Kingston University, FhG Fokus, University of Patras, Thales, Telefonica, CeBit.

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