Communication Costs Calculation in Hierarchical P2P-SIP networks

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***Abstract*—Due to they flexibility, robustness, and stretch, P2P-SIP networks are nowadays the subject of great research. These properties make that P2P-SIP networks are preferred to Client/Server traditional model. However, in P2P-SIP systems, as the number of users increases rapidly, exchanged messages in the network grows exponentially and them causes an overload of the bandwidth and a supplementary end-to-end delay. Several research work have attempted to reduce this overhead, especially by implementing hierarchical systems. Existing solutions do not offer generic and efficient method to reduce the bandwidth overload.**

In this paper, we propose an efficient and generic scheme in order to calculate the exact number of exchanged messages in the hierarchical overlay networks. Our proposed approach give a formula to find the exact value of the number of messages generated, knowing the number of nodes that compose the overlay network.

I. Introduction

In recent years, P2P communications are very popular. These are increasing day by day because of the interest that users discover there, but also because of the large volume of data passing through. In fact, P2P networks allow users to exchange files (texts, sounds, videos, ...). The combination of P2P and SIP (Session Initiation Protocol) allows users to communicate by telephone or video conference using P2P networks [1], giving P2P-SIP networks [2]. SIP is an application layer signaling protocol proposed by IETF to establish, modify and terminate multimedia sessions across global Internet. The many benefits of P2P-SIP networks such as robustness, scalability, scaling ..., [3] make these networks are in high demand. Day by day, the number of users of these overlays networks increases. It is the same for the amount of data to be exchanged. Thus the bandwidth is increasingly employed.

Since the number of users will continue to grow, so it is important and even essential to quantify the number of messages through the overlay network to make predictions for the future. In the existing literature [2], authors have attempted to reduce the overhead of bandwidth but failed to prevent it. To our knowledge, no paper has determined the exact value of the number of messages generated throughout the overlay network during the node lookup process.

In this paper, we calculate the exact number of messages produced by any HP2P-SIP architecture in the case of node lookups. In other words, regardless of the type of hierarchical architecture, we give a formula to find the exact value of the number of messages generated, knowing the number of nodes that compose the overlay network.

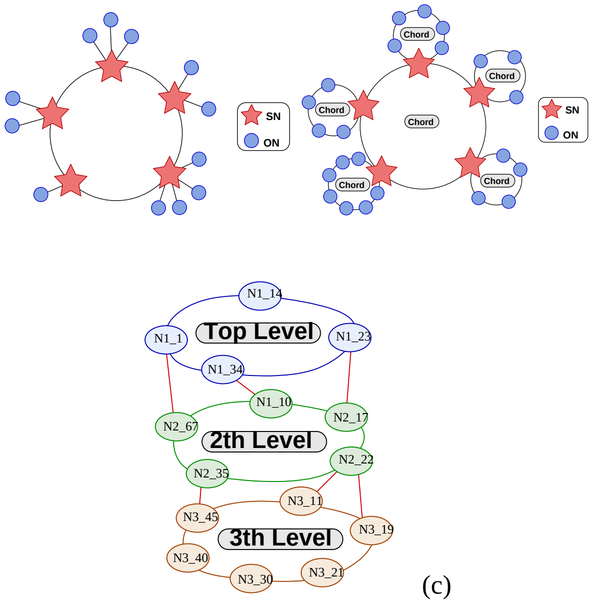
The remainder of the paper is organized as follows: in section II, we present some related work in P2P-SIP and HP2P-SIP. In section III, we present a Chord-based overlay, since Chord is the DHT we use in our case. The section IV is devoted to cost calculation in the case of lookup nodes. Finally, we give conclusion and open issues in section V.

II. Related Work

P2P-SIP networks are widespread with increasing multimedia communications over the Internet. Indeed, because of potential failures of Location Servers, Registration Servers and Redirect Servers of SIP protocol, several studies [1] combined the P2P networks with SIP. In other words, in a P2P-SIP network, all nodes are SIP servers. However, since some nodes are more powerful than others, some research work [4] have established a hierarchy of nodes. The most powerful nodes (processing speed, storage capacity, ...) called super nodes (SN) deal with registration and the location of other low capacity nodes called ordinary nodes (ON). This new structure gives rise to Hierarchical P2P-SIP networks. Many types of structuring exist:

- Structuring where SNs are grouped together in an overlay and the ONs are attached to them [4] (figure (a))
- Structuring where the SNs are grouped together in a main overlay. The ONs are also grouped together in other overlays. Each ON overlay is attached to a SN in the main overlay [5]. In each overlay (SN overlay as ON overlays), we can use the same Distributed Hash Table (DHT) (figure (b)) or different DHTs.
- Structuring where the SNs are grouped together in an overlay. The ONs are also grouped together in other overlays depending on their capacities [5] (figure (c)).

Several DHT algorithms have been proposed in the literature like Chord, Bamboo, Pastry, Tapestry etc. However, in this paper, we focus on the most popular DHT: Chord algorithm [6]. Therefore, in the following subsection, we specify Chord-based P2P-SIP overlay.



(a) (b)

(c)

III. Chord-based overlay

Chord has been suggested as a mandatory overlay to support P2P-SIP communication. As specified in [7], in Chord overlay, peers and resources are structured into a ring. Peers and resources are represented by integers $\mathcal{N}ode\mathcal{ID}/\mathcal{R}esource\mathcal{ID}$. The peer $\mathcal{ID}$ is produced by hashing the IP address of the particular peer, and the resource $\mathcal{ID}$ is obtained by hashing the data value. The $\mathcal{R}esource\mathcal{ID}$ is stored in the first peer which $\mathcal{ID} \geq \mathcal{R}esource\mathcal{ID}$. In addition, each peer has a Finger table which records $\log_2(\mathcal{N})$ successors to ensure the routing information [7], where $\mathcal{N} = 2^m$ is the number of peers in the ring and m the number of addressing bits.

IV. Lookup costs caculation

In this section, we conduct a theoretical study in order to find a formula that can give exact number of messages generated in each of the three types of architecture described above. As proved in [8] and in [9], the number of generated messages depends strongly on the location method used. Indeed in [8], authors have given the number of messages generated (generically) by a node, according to the research method used. In [9], authors treated the cost of research and maintenance only in a single domain architecture (figure (a)).

Contrary to [9], that use the number of exchanged messages by each node without giving its real value, in our study, we formally determine this latter according to [8]. After this, we use the obtained value in order to find a general formula giving the total number of generated messages in each architecture. Finally, in each architecture, we formally determine the exact number of exchanged messages in each routing method. In our case, we use Chord and focus only on the number of generated messages by the lookup nodes.

A. Default HP2P-SIP Architecture ($HP2P - SIP^{def}$)

This architecture is described in figure (a). We will recall some formulas used in [9]. In these formulas, the terms which we are interested are $\mathcal{R}_{LKP}$ ones ($\mathcal{R}_{LKP,ON}$ and $\mathcal{R}_{LKP,SN}$). This later represent the number of sent/received messages by a node (Super Nodes (SN) or Ordinary Nodes (ON)) during the LookuP (LKP) process. Thus, based on [8], we calculate this terms. To do this, we use the same notation as used by Zoels et *al.* in [9] and adapting them according to our case.

- $\mathcal{N}_{SN}$: number of Super Nodes (SN).
- $\mathcal{N}_{ON}$: number of Ordinary Nodes (ON).
- $\mathcal{N}_{ON_i}$: number of ON attached to a SN i.
- $\mathcal{R}_{LKP,ONj}$: number of sent/received messages by an ordinary node j during ordinary nodes lookup
- $\mathcal{R}_{LKP,SN_i}$: number of sent/received messages by super node i during super nodes lookup.
- $\mathcal{N}_{mess}^{HP2P-SIP^{def}}$: number of sent/received messages by all SN in default HP2P-SIP.

In [9], Zoels et *al.* show that the total number of generated messages for each super node i (SN_i) and each ordinary node j (ON_j), that performs the lookups process in a chord ring are obtained as follows:

$$\mathcal{M}_{(SN_i)} = \mathcal{R}_{LKP,SN_i} \times \log_2(\mathcal{N}_{SN}) \tag{1}$$

$$\mathcal{M}_{(ON_j)} = \mathcal{R}_{LKP,ON_j} \times [\log_2(\mathcal{N}_{SN}) + 1] \tag{2}$$

Since in a chord ring, the routing table of a node comprises $log_2(n)$ entries [7]. Therefore, using equations 1 and 2, we calculate the total number of generated messages (noted $\mathcal{N}_{mess}^{HP2P-SIP^{def}}$) by all nodes in $HP2P-SIP^{def}$ as follows:

$$\mathcal{N}_{mess}^{HP2P-SIP^{def}} = \sum_{i=1}^{\mathcal{N}_{SN}} \mathcal{M}_{(SN_i)} + \sum_{i=1}^{\mathcal{N}_{SN}} \sum_{j=1}^{\mathcal{N}_{ON_i}} \mathcal{M}_{(ON_j)} \tag{3}$$

$$\begin{aligned}\mathcal{N}_{mess}^{HP2P-SIP^{def}} &= \sum_{i=1}^{\mathcal{N}_{SN}} \mathcal{R}_{LKP,SN_i} \times \log_2(\mathcal{N}_{SN}) \\ &+ \sum_{i=1}^{\mathcal{N}_{SN}} \sum_{j=1}^{\mathcal{N}_{ON_i}} \mathcal{R}_{LKP,ON_j} \times [\log_2(\mathcal{N}_{SN}) + 1]\end{aligned}$$

Finally, after reorganization, the total number of generated messages in $HP2P - SIP^{def}$ is:

$$\begin{aligned}\mathcal{N}_{mess}^{HP2P-SIP^{def}} &= \log_2(\mathcal{N}_{SN}) \times \sum_{i=1}^{\mathcal{N}_{SN}} \mathcal{R}_{LKP,SN_i} \\ &+ [\log_2(\mathcal{N}_{SN}) + 1] \times \sum_{i=1}^{\mathcal{N}_{SN}} \sum_{j=1}^{\mathcal{N}_{ON_i}} \mathcal{R}_{LKP,ON_j}\end{aligned} \tag{4}$$

As the number of exchanged messages depends on the lookup method used [8], after having determined a generic formula (Equation 4), we will focus on the cost of each lookup method. Three families of lookup methods exist: iterative or exhaustive-iterative, full-recursive or source-routing-recursive (recursive) and semi-recursive. According to [10], the exhaustive-iterative method consumes more bandwidth than the iterative method; and source-routing-recursive method is less expensive than full-recursive method. Since in our case we are interested in minimizing the occupation of bandwidth, we will work with iterative methods, recursive and semi-recursive. In the remain of this paper, we use the following notations:

• Ite=iterative • Rec=recursive • SRec=semi-recursive

• n is the number of nodes participating to the distribution

1) Iterative lookup: In [8], Bryan et *al*. show that, in the iterative lookup method, the number of generated messages by each node is $2 \times (n-1)$. Thus, we apply this in different $\mathcal{R}_{LKP}$ and we obtain:

$$\mathcal{R}_{LKP,SN_i} = 2(\mathcal{N}_{SN} - 1) \quad (5)$$

$$\mathcal{R}_{LKP,ON_j} = 2(\mathcal{N}_{SN} - 1) + 2 \ = \ 2\mathcal{N}_{SN} \quad (6)$$

Remark 4.1: For ONs, as the lookup is done by the SNs, we have $2(\mathcal{N}_{SN} - 1)$ [9]. In addition, for an ON, we must consider the message sent to its SN and the message it receives from it in case of response. Thus, we must add $+2$. For all SNs, the total number of generated messages is:

$$\sum_{i=1}^{\mathcal{N}_{SN}} \mathcal{R}_{LKP,SN_i} = \sum_{i=1}^{\mathcal{N}_{SN}} 2(\mathcal{N}_{SN}-1) = 2\times\mathcal{N}_{SN}\times(\mathcal{N}_{SN}-1) \quad (7)$$

For all ONs, the total number of generated messages is:

$$\sum_{j=1}^{\mathcal{N}_{ONi}} \mathcal{R}_{LKP,ON_j} = \sum_{j=1}^{\mathcal{N}_{ON_i}} 2\mathcal{N}_{SN} = 2 \times \mathcal{N}_{ON_i} \times \mathcal{N}_{SN} \quad (8)$$

By injecting equations (7) and (8) in (4), we deduce the total number of generated messages (noted $\mathcal{N}_{mess}^{HP2P-SIP^{def}}(Ite)$).

$$\mathcal{N}_{mess}^{HP2P-SIP^{def}}(Ite) = \log_2(\mathcal{N}_{SN})\times2\times\mathcal{N}_{SN}\times(\mathcal{N}_{SN}-1) + [\log_2(\mathcal{N}_{SN}) + 1] \times \sum_{i=1}^{\mathcal{N}_{SN}} 2 \times \mathcal{N}_{ON_i} \times \mathcal{N}_{SN}$$

Finally, after reorganization and simplification, we obtain:

$$\mathcal{N}_{mess}^{HP2P-SIP^{def}}(Ite) = 2\times\mathcal{N}_{SN}\times[(\mathcal{N}_{SN}-1)\times\log_2(\mathcal{N}_{SN}) + [\log_2(\mathcal{N}_{SN}) + 1] \times \sum_{i=1}^{\mathcal{N}_{SN}} \times\mathcal{N}_{ON_i}] \quad (9)$$

2) Recursive lookup: Here, the number of generated messages by a node is $2 \times (n - 1)$ [8]; Thus, the total number of messages generated by all nodes (noted $\mathcal{N}_{mess}^{HP2P-SIP^{def}}(Rec)$) is the same that in iterative. Thus

$$\mathcal{N}_{mess}^{HP2P-SIP^{def}}(Ite) = \mathcal{N}_{mess}^{HP2P-SIP^{def}}(Rec) \quad (10)$$

We note this $\mathcal{N}_{mess}^{HP2P-SIP^{def}}(Ite/Rec)$

3) Semi-Recursive lookup: in semi-recursive method, the number of messages generated by a node is n [8]. Thus,

$$\mathcal{R}_{LKP,SN_i} = \mathcal{N}_{SN} \quad (11)$$

$$\mathcal{R}_{LKP,ON_j} = \mathcal{N}_{SN} + 2 \quad (12)$$

Then, we obtain :

$$\sum_{i=1}^{\mathcal{N}_{SN}} \mathcal{R}_{LKP,SN_i} = \sum_{i=1}^{\mathcal{N}_{SN}} \mathcal{N}_{SN} = (\mathcal{N}_{SN})^2 \quad (13)$$

$$\sum_{j=1}^{\mathcal{N}_{ON_i}} \mathcal{R}_{LKP,ON_j} = \sum_{j=1}^{\mathcal{N}_{ON_i}} (\mathcal{N}_{SN}+2) = \mathcal{N}_{ONi}\times(\mathcal{N}_{SN}+2) \quad (14)$$

By injecting equations 13 and 14 in the equation 4, we deduce the total number of generated messages (noted $\mathcal{N}_{mess}^{HP2P-SIP^{def}}(SRec)$) in semi-recursive method.

$$\mathcal{N}_{mess}^{HP2P-SIP^{def}}(SRec) = (\mathcal{N}_{SN})^2 \times \log_2(\mathcal{N}_{SN}) + (\mathcal{N}_{SN} + 2) \times [\log_2(\mathcal{N}_{SN}) + 1] \sum_{i=1}^{\mathcal{N}_{SN}} \mathcal{N}_{ON_i} \quad (15)$$

Remark 4.2: In the particular case we have the same number of ONs in each SN (*i.e.* $\mathcal{N}_{ON_i} = \mathcal{N}_{ON/SN}$), thus:

$$\sum_{i=1}^{\mathcal{N}_{SN}} \mathcal{N}_{ON_i} \ = \ \sum_{i=1}^{\mathcal{N}_{SN}} \mathcal{N}_{ON/SN} \ = \ \mathcal{N}_{SN} \times \mathcal{N}_{ON/SN} \quad (16)$$

Therefore:

• In Ite/Rec methods, number of exchanged messages is:

$$\mathcal{N}_{mess}^{HP2P-SIP^{def}}(Ite/Rec) = 2\times\mathcal{N}_{SN}\times[(\mathcal{N}_{SN}-1)\times(\log_2(\mathcal{N}_{SN})) + \mathcal{N}_{SN} \times \mathcal{N}_{ON/SN} \times (\log_2(\mathcal{N}_{SN}) + 1)] \quad (17)$$

• In SRec method, the number of generated messages is:

$$\mathcal{N}_{mess}^{HP2P-SIP^{def}}(SRec) = (\mathcal{N}_{SN})^2\times\log_2(\mathcal{N}_{SN})+\mathcal{N}_{SN}\times\mathcal{N}_{ON/SN} \times (\mathcal{N}_{SN} + 2) \times [\log_2(\mathcal{N}_{SN}) + 1] \quad (18)$$

B. Multi-Level HP2P-SIP Architecture ($HP2P - SIP^{ML}$)

This architecture is described in figure (c). In our case, sub-levels as top level use CHORD as DHT.

- K: number of sub levels.
- $\mathcal{N}_{P_i}$: number of nodes in sub-level i.
- $\mathcal{N}_{SN}$: number of super nodes in top level.
- $\mathcal{R}_{SN_i}$: number of sent/received messages by an SN i.
- $\mathcal{R}_{P_i}$: number of sent/received messages by a node i.

In $HP2P - SIP^{ML}$ architecture, as all nodes participate in the distribution in their own level, we obtain:

- The number of messages (sent/received) generated (noted $\mathcal{M}_{(SN_i)}$) by a super node i that performs the lookup is :
$$\mathcal{M}_{(SN_i)} = \mathcal{R}_{SN_i} \times \log_2(\mathcal{N}_{SN}) \quad (19)$$
- The number of messages generated (noted $\mathcal{M}_{(P_j)}$) by node j belonging to sublevel i that performs lookup is :
$$\mathcal{M}_{(P_j)} = \mathcal{R}_{P_j} \times \log_2(\mathcal{N}_{P_i}) \quad (20)$$

Thus, the total number of messages sent and received in level i (noted $\mathcal{N}_{mess/i}^{HP2P-SIP^{ML}}$) and in Top Level ($TL$) (noted $\mathcal{N}_{mess/TL}^{HP2P-SIP^{ML}}$) are given by the following equations:

- Total number of messages sent and received in Top level:

$$\mathcal{N}_{mess/TL}^{HP2P-SIP^{ML}} = \sum_{i=1}^{\mathcal{N}_{SN}} \mathcal{M}_{(SN_i)} = \log_2(\mathcal{N}_{SN})\times\sum_{i=1}^{\mathcal{N}_{SN}} \mathcal{R}_{SN_i} \quad (21)$$

- Total number of messages sent and received in level i:

$$\mathcal{N}_{mess/i}^{HP2P-SIP^{ML}} = \sum_{j=1}^{\mathcal{N}_{P_i}} \mathcal{M}_{(P_j)} = \log_2(\mathcal{N}_{P_i}) \times \sum_{j=1}^{\mathcal{N}_{P_i}} \mathcal{R}_{P_j} \quad (22)$$

According to equations 21 and 22, the total number of generated messages in Multi-Level HP2P-SIP is:

$$\mathcal{N}_{mess}^{HP2P-SIP^{ML}} = \mathcal{N}_{mess/TL}^{HP2P-SIP^{ML}} + \sum_{i=1}^{k} \mathcal{N}_{mess/i}^{HP2P-SIP^{ML}} \quad (23)$$

Finally, after reorganization and simplification, we obtain:

$$\mathcal{N}_{mess}^{HP2P-SIP^{ML}} = \log_2(\mathcal{N}_{SN}) \times \sum_{i=1}^{\mathcal{N}_{SN}} \mathcal{R}_{SN_i} + \sum_{i=1}^{k} (\log_2(\mathcal{N}_{P_i})) \times \sum_{j=1}^{\mathcal{N}_{P_i}} \mathcal{R}_{P_j} \quad (24)$$

In the following, we determine the total number of generated messages for each method (*iterative, recursive and semi-recursive)* in Multi-Level HP2P-SIP architecture.

1) For iterative and recursive methods: The number of generated messages by a node is:

- in each sub-level i, as all $\mathcal{N}_{P_i}$ nodes participate in the distribution, we have: $\mathcal{R}_{P_j} = 2 \times (\mathcal{N}_{P_i} - 1)$
- in the top level, as all $\mathcal{N}_{SN}$ nodes participate in the distribution, we have: $\mathcal{R}_{SN_i} = 2 \times (\mathcal{N}_{SN} - 1)$

Thus, the total number of generated messages by all nodes is:

- in each sub-level i : $\sum_{j=1}^{\mathcal{N}_{P_i}} \mathcal{R}_{P_j} = 2 \times \mathcal{N}_{P_i} \times (\mathcal{N}_{P_i} - 1)$
- in the top level : $\sum_{i=1}^{\mathcal{N}_{SN}} \mathcal{R}_{SN_i} = 2 \times \mathcal{N}_{SN} \times (\mathcal{N}_{SN} - 1)$

Thus, by injecting in equation 21 and equation 22, we obtain:

- the total number of generated messages in top level is :

$$\mathcal{N}_{mess/TL}^{HP2P-SIP^{ML}}(Ite/Rec) = 2 \times \mathcal{N}_{SN} \times (\mathcal{N}_{SN} - 1) \times (\log_2(\mathcal{N}_{SN})) \quad (25)$$

- the number of messages generated in all sub-levels is:

$$\sum_{i=1}^{K} \mathcal{N}_{mess/i}^{HP2P-SIP^{ML}}(Ite/Rec) = 2 \times \sum_{i=1}^{K} \mathcal{N}_{P_i} \times (\mathcal{N}_{P_i} - 1) \times (\log_2(\mathcal{N}_{P_i})) \quad (26)$$

Using equations 25 and 26, we calculate the total number of generated messages in Multi-Level HP2P-SIP architecture by iterative or recursive method as follows:

$$\mathcal{N}_{mess}^{HP2P-SIP^{ML}}(Ite/Rec) = 2 \times \mathcal{N}_{SN} \times (\mathcal{N}_{SN} - 1) \times \log_2(\mathcal{N}_{SN}) + 2 \times \sum_{i=1}^{K} \mathcal{N}_{P_i} \times (\mathcal{N}_{P_i} - 1) \times \log_2(\mathcal{N}_{P_i}) \quad (27)$$

2) For semi-recursive method: According to [8] and by proceeding in the same way, we obtain:

- in each sub-level i : $\mathcal{R}_{P_j} = \mathcal{N}_{P_i}$
- in the top level : $\mathcal{R}_{SN_i} = \mathcal{N}_{SN}$

Thus, by injecting in equation 21 and equation 22, we obtain:

$$\mathcal{N}_{mess/TL}^{HP2P-SIP^{ML}}(SRec) = (\mathcal{N}_{SN})^2 \times (\log_2(\mathcal{N}_{SN})) \quad (28)$$

and

$$\sum_{i=1}^{K} \mathcal{N}_{mess/i}^{HP2P-SIP^{ML}}(SRec) = \sum_{i=1}^{K} (\mathcal{N}_{P_i})^2 \times (\ log_2(\mathcal{N}_{P_i})) \quad (29)$$

Therefore, we deduce the total number of generated messages in $HP2P-SIP^{ML}$ by the semi-recursive method as follows:

$$\mathcal{N}_{mess}^{HP2P-SIP^{ML}}(SRec) = (\mathcal{N}_{SN})^2 \times (\log_2(\mathcal{N}_{SN})) + \sum_{i=1}^{K} (\mathcal{N}_{P_i})^2 \times (\log_2(\mathcal{N}_{P_i})) \quad (30)$$

Remark 4.3: In the particular case where we have, in all sub-levels, the same number of nodes (noted $\mathcal{N}_P$), we'll have:

- In iterative and Recursive methods:

$$\sum_{i=1}^{K} \mathcal{N}_{mess/i}^{HP2P-SIP^{ML}}(Ite/Rec) = 2 \times K \times \mathcal{N}_P \times (\mathcal{N}_P - 1) \times (\log_2(\mathcal{N}_P)) \quad (31)$$

The total number of generated messages is :

$$\mathcal{N}_{mess}^{HP2P-SIP^{ML}}(Ite/Rec) = 2 \times \mathcal{N}_{SN} \times (\mathcal{N}_{SN} - 1) \times (\log_2(\mathcal{N}_{SN})) + 2 \times K \times \mathcal{N}_P \times (\mathcal{N}_P - 1) \times (\log_2(\mathcal{N}_P)) \quad (32)$$

- In Semi-Recursive method:

$$\sum_{i=1}^{K} \mathcal{N}_{mess/i}^{HP2P-SIP^{ML}}(SRec) = K \times \mathcal{N}_P^2 \times (\log_2(\mathcal{N}_P)) \quad (33)$$

The total number of generated messages is :

$$\mathcal{N}_{mess}^{HP2P-SIP^{ML}}(SRec) = \mathcal{N}_{SN}^2 \times (\log_2(\mathcal{N}_{SN})) + K \times \mathcal{N}_P^2 \times (log_2(\mathcal{N}_P)) \quad (34)$$

C. Multi-Domain HP2P-SIP Architecture ($HP2P-SIP^{MD}$)

This architecture is described in figure (b). In our case, we use Chord as DHT in main domain and subdomains. With the same notation as for $HP2PSIP^{ML}$ and proceeding in the same way as with previous architectures, we obtain:
The number of exchanged messages in Multi-Domain HP2P-SIP Architecture (noted $\mathcal{N}_{mess}^{HP2P-SIP^{MD}}$) as follows.

$$\mathcal{N}_{mess}^{HP2P-SIP^{MD}} = \mathcal{N}_{mess/TL}^{HP2P-SIP^{MD}} + \sum_{i=1}^{k} \mathcal{N}_{mess/i}^{HP2P-SIP^{MD}} \quad (35)$$

After applying to different methods, we obtain:

- in iterative or recursive method:

TABLE I
COMPARISON BETWEEN HIERARCHICAL P2P-SIP ARCHITECTURES ACCORDING TO ROUTING METHOD USED

		Number of generated messages			
		$HP2P-SIP^{def}$		$HP2P-SIP^{ML}$ / $HP2P-SIP^{MD}$	
		Ite/Rec	SRec	Ite/Rec	SRec
Number of super nodes	20	211904	116469	531516	271347
	40	502128	263415	219076	114152
	60	837494	432362	155100	81680
	80	1204557	616842	152784	80210
	100	1507442	768144	177195	92114

$$\mathcal{N}_{mess}^{HP2P-SIP^{MD}}(Ite/Rec) = 2\times\mathcal{N}_{SN}\times(\mathcal{N}_{SN}-1)\times(\log_2(\mathcal{N}_{SN})) + 2\times K\times\mathcal{N}_P\times(\mathcal{N}_P-1)\times(\log_2(\mathcal{N}_P)) \quad (36)$$

- in semi-recursive method:

$$\mathcal{N}_{mess}^{HP2P-SIP^{MD}}(SRec) = (\mathcal{N}_{SN})^2\times(\log_2(\mathcal{N}_{SN})) + K\times(\mathcal{N}_P)^2\times(\log_2(\mathcal{N}_P)) \quad (37)$$

D. Comparison between $HP2P-SIP^{def}$ vs $HP2P-SIP^{ML}$ and $HP2P-SIP^{MD}$

In this section, our goal is to observe the evolution of the number of generated messages following the number of super nodes in the overlay network. We assume that the total number of nodes equal in different architectures and we fix this number at 1000 nodes (i.e $\mathcal{N}=1000$). Furthermore, we choose arbitrarily the number of super SNs and calculate the total number of generated messages. All calculated values are summarize in table I

- In $HP2P-SIP^{def}$, $\mathcal{N}=\mathcal{N}_{SN}+\mathcal{N}_{SN}\times\mathcal{N}_{ON/SN}$
  By choosing arbitrarily the values of $\mathcal{N}_{SN}$, we calculate $\mathcal{N}_{ON/SN}$, and replace in equation (17) and equation (18)
- In $HP2P-SIP^{ML}$ or $HP2P-SIP^{MD}$,
  $\mathcal{N}=\mathcal{N}_{SN}+K\times\mathcal{N}_P$.
  Similarly, by choosing arbitrarily the values of $\mathcal{N}_{SN}$, we calculate $\mathcal{N}_P$ in the same way we calculate $\mathcal{N}_{ON/SN}$. Then we calculate K and replace in equation (32) and equation (34). See that $\mathcal{N}_{mess}^{HP2P-SIP^{ML}}$ and $\mathcal{N}_{mess}^{HP2P-SIP^{MD}}$ have the same formula.

As the number of SN increases, the number of generated messages increases. This is due to the fact that the greater the number of SN increases, the architecture tends to a flat overlay network. In other words, the number of ON is reduced because some of them are selected to become SN. Therefore the number of nodes participating in the distribution becomes larger. Similarly, if we consider the recursive or iterative methods (columns 3 and 5) , the table shows that the $HP2P-SIP^{def}$ architecture generates more messages than architectures $HP2P-SIP^{ML}$ or $HP2P-SIP^{MD}$. It is the same when we consider the semi-recursive method (columns 4 and 6). Indeed, in $HP2P-SIP^{def}$, only the SN participate in the distribution. Now, in addition to their own messages, SN must support all messages of ON that are attached to them. That's why when they become more numerous, the number of messages is growing faster in $HP2P-SIP^{def}$ than in $HP2P-SIP^{ML}$ or $HP2P-SIP^{MD}$.

In addition, for an equal number of nodes, the architecture $HP2PSIP^{def}$ consumes more bandwidth than $HP2PSIP^{ML/MD}$. For example, if we implemente iterative or recursive method:
for a number of SN equal to 100 (in TABLE I), if we have messages with size 64 bits for example and a bandwidth of 10 megabytes per second, will require:

- $\frac{(1507442\times64)}{(10\times1024\times1024)}$ = 9.20 s, in $HP2PSIP^{def}$

  so that all messages pass across the network.
- $\frac{(177195\times64)}{(10\times1024\times1024)}$ = 1.08 s, in $HP2PSIP^{ML/MD}$

V. CONCLUSION AND OPEN ISSUES

In this paper, we have determined (for each location method) the number of messages that can be generated in a HP2P-SIP overlay network in the case of lookup process. This allows us to control the evolution of the number of messages as and as the number of users increases. So this gives us the opportunity to make predictions into the future.
In the case of our outlook, we will conduct an experimental study by simulations with OverSim simulator for comparing our theoritical values with experimental ones.

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