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## A Gossip-based Adaptive and Reliable Multicast Model on Hybrid P2P Overlay

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**Abstract:** Online games are receiving more and more attention due to the potential market. But how to implement information dissemination reliably and efficiently in gaming platform along with large or larger size of game users is urgent to be solved. Peer-to-peer (P2P) technology becomes more and more popular because it can massively reduce loads on backbone of Internet, pushing intelligence to the edge of Internet. Nowadays, P2P is turning towards hybrid model which integrates advantages of central model with fully distributed model. Hybrid model is also called a semi-structured model which considers the difference among peers. Peers are often divided into two branches, superpeer group and leafpeer group. Superpeers are often to designate more important tasks. It's widely applied in streaming, storage and IM etc. But how to disseminate messages on hybrid P2P reliably and efficiently is an open issue. Previous works often take tree-based multicast or flat probability model which cannot make a trade-off in reliability and efficiency. DouLaCast, a probability information dissemination model on hybrid P2P system, is presented in this paper which considers ability among peers and can select suitable peer to forward messages, improving reliability of multicast. Simulations demonstrate DouLaCast functions better than flat gossip method.

**Key words:** Superpeer, leafpeer, P2P overlay, multicast, probability selection, gossip

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### INTRODUCTION

During the past few years, arriving of FTTH (Fiber-to-the-home) and 3G techniques has contributed to clients' access internet with high speed in a wired or wireless style. According to reports by eNet, the market size of online game in China reached 5.5 billion in the first quarter, 2009, with a link-relative increase by 8.3% (<http://www.enet.com.cn>). It's very valuable to do some research on online gaming platform. Recent online game often contains massive players, from ten thousands to millions. Applications need to update users' states through sending messages periodically, such as coordinates of virtual characters or parameters to be maintained. In the traditional solution, servers send messages to clients periodically which may cause a long task queue at the server when facing massive clients, finally results in longer latency or even no response, decreasing the experience of players. It's necessary to find a new network architecture and information dissemination method to do reliable, scalable and efficient infrastructure supporting on online gaming platform. In this paper, we propose a multicast model on hybrid P2P architecture to satisfy applications.

Hybrid P2P topology, as a novel P2P one, gains more and more popularity in recent years. Its special feature

different from previous works is that it differentiates the capability of peers such as computing ability, storage space and bandwidth. It divides peers into several groups and different groups can afford different tasks. Usually the hybrid P2P system contains two groups, a superpeer group and leafpeer group (Chen *et al.*, 2010). Peers in superpeer group often are those who represent higher ability in hardware resource and bandwidth, with a longer online time. Their main role is index servers which serve leafpeers. They collect leafpeers' address and resource information and store in their cache for further operations. Superpeers can communicate with each other directly or indirectly by relaying style. They will exchange information in their caches for information dissemination. However, leafpeers act as clients in hybrid P2P system. They cannot communicate with each other and their resource uploading and retrieving should only be operated by their own superpeers.

Hybrid P2P model firstly constructs an efficient and reliable platform for diverse applications. The next step is to build suitable information exchanging mechanism on this platform. Information exchanging, also called information dissemination consists of information sending, forwarding and receiving. The classic hybrid P2P models includes KaZaA (Leibowitz *et al.*, 2003), GIA (Chawathe *et al.*, 2003) etc.

During the past years, two methods have mainly been employed for multicasting in P2P system: Multicast tree-based (Gupta *et al.*, 2006) and flooding-based (Eugster *et al.*, 2004). Tree-based model is highly efficient at data transferring but not suitable in dynamic overlay environment. Modern P2P system often contains massive peers and these peers may join in or leave from the system freely which causes network churn. A multicast tree can be seriously affected by churn, resulting in frequently rebuilding. The efficiency of the tree is totally broken for churn in dynamic overlay. Flooding-based model can guarantee reliability but leads to low scalability in large-scale P2P system. Generally, flooding-based model is deployed on a flat fully distributed P2P topology, without considering the differences among peers, resulting in blind relay peer selection which may lead to low ability peer to be relay peer and becomes bottleneck in transferring period and finally decreases reliability of multicast. It's necessary to find a new multicast model on hybrid P2P topology to implement reliable and efficient information dissemination.

In this study, a new multicast model-DouLaCast on hybrid P2P architecture is proposed. DouLaCast is built on an adaptive hybrid P2P topology which considers the differences of peers and can differentiate the ability of peers. Only superpeers can forward messages in hybrid P2P topology, extremely increasing reliability of multicast and decreasing the possibility of weak peers to be relay nodes that accordingly leads to bottleneck of transferring. And limiting leafpeers joining multicast can reduce redundant data transferring, improving efficiency of dissemination. Otherwise, DouLaCast can be aware of the real time loads in system, dynamically select suitable peer to act as relay peer for forwarding messages and achieve load balancing function. The simulations validate our idea.

Peer-to-Peer technology is now a hot issue in the research field of network applications. Generally speaking, this technology refers to P2P systems (Wang and Sun, 2009; Wang *et al.*, 2011, 2010; Mekki and Fezza, 2009) or P2P computing (Guo *et al.*, 2007; Modarresi *et al.*, 2008, 2009). Literature most concerns data stream transmission (Chen *et al.*, 2011; Hoong and Matsuo, 2008).

NewsCast was proposed by Jelasity *et al.* (2006) which uses gossip to implement flat gossip information dissemination, such as computing the extreme result of special values. It only needs local neighbor view to function without knowing global status. It's only a framework but does not provide detailed multicast algorithm. And in the same year, Anne proposed a multicast method in large-scale

overlay (Anne-Marie *et al.*, 2003) which takes a hierarchical structure to control redundant data transferring and update cache with time-based style. But in that method, efficient multicasting depends on predefined parameter setting such as system size and etc. Th. Eugster *et al.* (2003) proposed Lpbcast that is a lightweight probability broadcast protocol. It optimizes the management of memory storage and will delete those messages which are forwarded more than others. However, its reliability relies on the randomness of underlying topology.

A systematic analysis on gossip-based protocol was presented by Tanaraksiritavorn and Mishra (2004). The paper points out the relationship between performance and fan-out and proposes an experimental base for gossip-based multicast protocols.

SophiNode (Zhang *et al.*, 2005) is a distributed electronic business framework which takes biased information dissemination. It will judge the popularity of a message before forwarding it. The bigger popularity a message is, the less possibility it will be forwarded which helps unusual message cover the whole overlay. But the popularity of a message should be judged by a well AI mechanism which makes it not applicable in current P2P system.

Gupta *et al.* (2006) proposed a gossip-based multicast on multi-layer architecture. It's built based on a tree structure which will be severely affected under dynamic environment.

RingCast is a model that combines deterministic dissemination with probability dissemination. When the message reaches a number of forwarding times, the forwarding will transfer to be deterministic to increase the coverage of multicast. But how to define suitable ratio of deterministic is an open issue (Voulgaris and van Steen, 2007).

A uniform buffering policy was proposed by Ozkasap *et al.* (2009). Its aim was to make data buffers distribute more uniformly. But it doesn't consider the different ability among peers, resulting in buffering peer unaffordable for needs of applications.

### **DouLaCast-multicast on double-layer P2P**

**Hybrid P2P Infrastructure:** In this study, the hybrid P2P model is Firas (Chen *et al.*, 2010) which is an adaptive superpeer-based overlay, utilizing virtual coordinate system and gossip style to construct.

Its mechanism is to use distributed grouping algorithm to divide peers into several groups in terms of their ability and then select groups with high ability as superpeers. The architecture of Firas is described in Fig. 1. There are three main parts in Firas: Peer

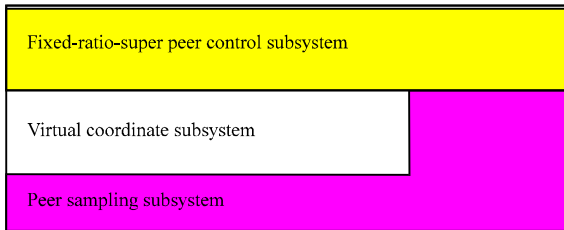


Fig. 1: Architecture of Firas

sampling subsystem, virtual coordinate subsystem and fixed-ratio-superpeer control subsystem. Here, just state the nature and principle of Firas without involving any concrete implementations.

Peer sampling subsystem provides nodes a capability of retrieving underlay peers. There are several kinds of peer sampling service, such as NEWSCAST (Jelasy et al., 2006).

Virtual coordinate subsystem provides nodes a quick access to know the latency between itself and the given node. Vivaldi (Dabek et al., 2004) is thought to be a precise solution for self-organized system without landmarks.

Fixed-ratio-superpeer control subsystem provides the capability for controlling the ratio of superpeers in the system which maintains the ratio of superpeers relatively stable. No matter how many peers join in or leave from the overlay randomly, we can always elect adaptive number of superpeers to provide services for client peers according to the constant proportion of superpeers.

Because of its internal structure described above, Firas provides us an adaptive and scalable infrastructure to deploy other applications.

**Multicast on Hybrid P2P Architecture:** In this study, a new probability multicast model DouLaCast (Double Layer Gossip Multicast) is presented which is built on Firas, considering the differences among peers, making superpeer to forward messages and contains a load-aware unit to retrieve real loading state on superpeers to make forwarding traffic distributed uniformly.

Supposing a P2P network contains N peers, each peer is identified by a unique identifier,  $n_1, n_2, n_3, \dots, n_N$ . Superpeers can join data forwarding, while leafpeers can only send message as source peer or receive messages. And superpeers contain four function units listed as follows.

- **Data dissemination unit:** Executes data dissemination and other related operations
- **Buffer management unit:** Handles the buffers used in dissemination

Table 1: Data structures and parameters used in DouLaCast

| Name        | Comment  |
|-------------|--|
| SP          | A superpeer in P2P overlay   |
| d           | A data message in dataBuffer   |
| db          | DataBuffer which stores data messages on superpeer                         |
| gn          | The No. of times a message gossiped  |
| MAX_GN      | The maximum times of a message can be gossiped                             |
| Id          | The identifier of a data message   |
| F           | Fanout parameter, the number of peers need to forward gossip messages      |
| fdList      | A list of superpeers can forward gossip messages to                        |
| groupId     | The identifier of a multicast group  |
| LastRecvMid | The maximum ID of data message received                                    |
| MissingDB   | A dataBuffer used to store identifiers of missing data messages            |
| gpm         | A gossip message contains data digest for gossiping                        |
| ALPHA       | Indicates degree of loads on a superpeer                                   |
| leList      | Neighbor list which stores leafpeers of a superpeer                        |
| IB          | Index buffer which stores identifiers of data from a superpeer's leafpeers |

- **Load-aware unit:** Be aware the real loading in recent time on superpeer and then adjust forwarding policy
- **Index management unit:** Maintains index cache on superpeer

Table 1 gives data structure and parameter descriptions used in multicast algorithms executed by DouLaCast.

**Data dissemination unit:** Function of this unit need not extra support from other modules. Its main functions includes: (1) superpeer periodically send gossip messages to tell other peers its own digests. (2) superpeer generates data messages and then sends them to multicast group. The detailed multicast algorithm is described in algorithm 1 to 3.

**Algorithm 1-3: Details of data dissemination**

**Buffer management unit:** Divided into two modules, one is to identify some data as garbage collected, avoiding useless requests on such data, the other is API for up-level applications to retrieve data in buffer.

**Load-aware unit:** Its main function is to be aware load on superpeer. It helps superpeer decide whether to join forwarding in terms of recent loads on own which is beneficial to P2P system. This unit will collect traffic statistics every LT to adjust forwarding policy. The details are described in algorithm 4.

Algorithm 1: Generates data digest and gossips digest on superpeer SP

```

Do forever
    wait(DT)
    for each data d in SP.db
        if (d.gn < MAX_GN) //not exceed limit times
            put d.Id into sendbuf
            d.gn++
        end if
    end for

```

```

if (sendbuf.size>0)
set avgLoad = average ALPHA of superpeers in SP's fdList
select F superpeers whose ALPHA is bigger than avgLoad in
fdList randomly
send sendbuf to selected F superpeers
end if

```

Algorithm 2: Generates data message and multicast data message on superpeer SP

```

When a superpeer generates a data message d
insert(d, db)
select F superpeers in fdList to gossip d
When receiving a data message d
if (d.groupId == SP.groupId) and (d is not duplicate)
insert(d, SP.db)
set avgLoad = average ALPHA of superpeers in SP's fdList
select F superpeers whose ALPHA is bigger than avgLoad in
fdList randomly
forward d to selected F superpeers
end if
Function insert(d, db)
if (d.Id == LastRecvMid) //receive the same data message
discard d
else
put d into db
if (d.Id<LastRecvMid) //receive the missed data message
remove d.Id from MissingDB
endif
if (d.Id>(LastRecvMid+1)) //missed some data messages
put missingIds between d.Id and LastRecvMid into
MissingDB
order MissingDB by Ids in ascending order
LastRecvMid = d.Id
endif
if (d.Id == (LastRecvMid+1)) //receive and
append message into buffer
LastRecvMid = d.Id
endif
end if

```

Algorithm 3: Receive gossip message on superpeer SP

```

When receiving a gossip message gpm from a neighbor member m
if (gpm.groupId == SP.groupId)
for each d.Id in gpm
if (d.Id>LastRecvMid) //find some missing data message
put d.Id into MissingDB
end if
for each missingId in MissingDB
if (d.Id == missingId) //find some missingIds in gpm
if (curReqTimes<ReqLimit) and (LastReq != d.Id)
put d.Id into ReqBuffer
end if
end if
end for
end for
send ReqBuffer to m with probability SEND_PROB
add m into fdList
end if

```

Algorithm 4: Details of Load-aware

**Index management unit:** the function is to collect data digests from leafpeers and update periodically. The details are described in Algorithm 5.

Algorithm 4: Load-aware on SP

```

Do forever
wait (LT)

```

```

set TOTAL_DATA = the number of data messages forwarded during
recent LT
set FD_NUM = the number of neighbors in fdList
set ALPHA = TOTAL_DATA/FD_NUM
set TOTAL_DATA = 0 //reset TOTAL_DATA

```

**Algorithm 5: Details of index management:** Leafpeers cannot forward messages so their architecture is less complicated than superpeers. They can only receive messages from their own superpeers and send messages as source peer to their superpeers. It's noticed that the traffic can be reduced for weak leafpeers who don't join forwarding during multicast, resulting in low overhead. And load-aware module helps select those low loading superpeers to be relay peer which makes loads distributed more uniformly. Finally DouLaCast gives full play to hybrid P2P model and improves the reliability and efficiency of the whole P2P system.

Algorithm 5: Index management on SP

```

Do forever
wait (IMT)
for each lp in SP.lelist
for each d.Id in lp.DB
if (d.Id does not exist in SP.IB)
put d.Id into SP.IB
end if
end for
end for

```

## SIMULATIONS

**Simulation platform and simulation parameters:** In order to validate the performance of DouLaCast, we choose to simulate it and all of simulations are run on PeerSim (<http://peersim.sourceforge.net/>) which is a cycle-based simulator for large-scale overlay networks simulation. Each simulation is run 10 times and then gets an average value. The PeerSim is run at a HP pavilion computer with 2.2 GHz CPU.

In simulations each peer's address and identity is denoted by a unique identifier. It's supposed that communications between peers are provided by underlying physical links, such as Internet. The latency between two peers is determined by Euclidean distance between two peers defined by Vivaldi.

The reliability and dissemination cost of DouLaCast is analyzed during different network environments. The predefined multicast groups are supposed to exist in multicasting. In another word, the process of how to join a multicast group is not considered. The initial configuration of simulation is set as follows: Network size is 16384. The parameter k is 50 and the number of superpeer group is set to 1 or 2. The parameter PR = 0.02 or 0.04. The size of multicast group is set to 64, 256 or 1024, peers is selected from the overlay randomly. The

maximum forwarding times of gossip message MAX\_GN is set to be 10. The forwarding fan-out is 1, meaning only forwarding to one peer at one time.

**Experiments and analysis:** Here we define atomic multicast as that each peer in multicast group can receive the gossip message from the source peer during multicasting process. The atomicity of multicast is a very important metric to measure the reliability of multicasting algorithm. The results show in Fig. 2.

From the Fig. 2a, the smaller of multicast group, the better performance of DouLaCast when the same ratio of superpeer and neighbor view size of superpeer. The reason is larger multicast group will increase the difficulty of messages receiving by each peer in multicast group, resulting in low reliability of DouLaCast. But larger PR value means more superpeer in overlay will leads to more superpeer joining multicast and increase the probability of

message receiving by each peer in one multicast group. Otherwise, under the same PR value, if increasing the connectivity of superpeers ( $View_{sp}$ ) also can get a better multicast performance.

Figure 2b lists the reliability of DouLaCast, flooding algorithm and flat gossip algorithm. It's observed that no matter in which initial configuration, DouLaCast functions better than flat gossip algorithm but inferior to flooding algorithm. The reason is that flooding will forward message to each neighbor during multicasting but not probability forwarding which leads to full coverage of peers in overlay and incurs more redundant traffic. It's also noticed that the reliability of DouLaCast will decrease along with larger overlay size. But the decreasing speed performs better than flat gossip algorithm. The reason is limited forwarding times can not cover every peer in one multicast group under massive P2P overlay.

## CONCLUSION AND FUTURE WORK

In this study, we presented a new multicast model-DouLaCast on hybrid P2P system which uses the feature of underlying hybrid P2P to differentiate from peers to achieve reliability of multicast. The two main reason are listed as follows:

- In hybrid P2P model, only superpeer can join in message forwarding which avoids weak leafpeers to be relay peer that may become a bottleneck, resulting in decreasing the reliability of multicast
- DouLaCast can select suitable forwarding neighbor in terms of their ability and real loads, avoiding blind neighbor selection causing bottleneck, resulting in load-balancing in system. In a word, DouLaCast can improve the reliability of multicasting in P2P system and reduce redundant traffic

As for future work, a realistic prototype of DouLaCast with Java can be implemented to test and verify the protocol and its deployment on Internet to test its performance under an actual network environment is also promising for near vista.

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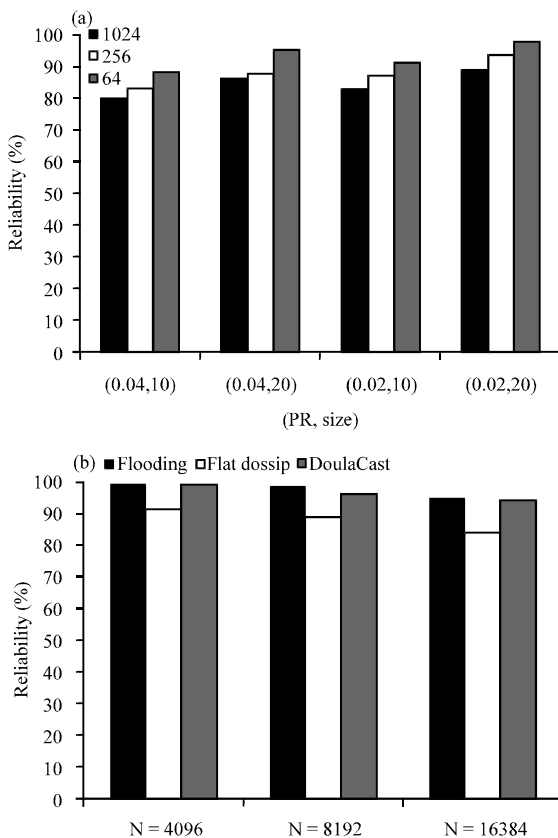


Fig. 2: Comparison of reliability of DouLaCast, (a) Comparison of reliability of DouLaCast with specified PR,  $View_{sp}$  at different size of multicast groups and (b) Comparison of reliability of DouLaCast and other multicast protocols with PR = 0.02, Group Size = 256

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