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MOVING P2P LIVE STREAMING TO MOBILE AND UBIQUITOUS ENVIRONMENT

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Abstract. Media streams distribution over a wired network to static hosts can be realized by Client/Server mode or Peer-to-Peer overlay networks. However, if the end hosts are mobile over heterogeneous wireless access networks, one needs to consider many operational issues such as network detection, handoff, join and leave latency, and desired level of quality of service, as well as caching. In the latest researches, one popular P2P live streaming system, called AnySee, over the wired network, has been deployed and widely used. Based on the AnySee system, this paper proposed and implemented one hybrid live streaming system, AnySee-Mobile, under wired and wireless environment. In the system, one wireless peer will be selected to act as an agent. One agent has two main functions, to request media from P2P overlay network as a normal peer, and to multicast media to WLAN as a multicast source. In this paper we study, how to elect one multicast agent in WLAN. Several experimentations have been made and proved that the system has good user experiences and performances.

Keywords: Peer-to-peer, live streaming, agent, mobile

1 INTRODUCTION

Recently, the peer-to-peer systems consisting of a dynamically changing set of nodes connected via the Internet have gained tremendous popularity. While initially conceived a popularized for the purpose of file sharing, P2P has emerged as a general paradigm for the construction of resilient, large-scale, distributed services and applications, such as live streaming services [1]. With the help of efficient overlay multicast, millions of users over the Internet have enjoyed multimedia broadcasting services with best-effort quality, but lack of large-scale users in mobile and ubiquitous environment. Third generation (3G) telecommunication services or Wi-Fi based WLAN networks promise to provide Internet access, such as downloading multimedia content or streaming, to mobile users having PDAs or mobile phones. One interesting idea how to extend P2P based live streaming services for large-scale users of mobile and ubiquitous environment [2]. End nodes in WLAN share frequencies and connect with each other via wireless router (also referred to as wireless access point, AP). Hereby, WLAN network has the following characteristics: mobility, dynamics, congestion and sharing links. It is difficult to move P2P live streaming services into mobile and ubiquitous environment. We should face the following problems: i) how to distribute media data to all peers with good quality; ii) how to decrease the impact from mobility and dynamic of mobile peers; iii) how to decrease the traffic congestion in WLAN.

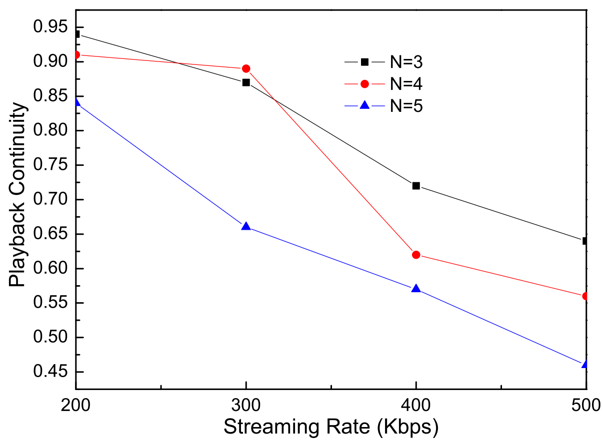

Fig. 1. One typical p2p overlay multicast in WLAN

Traditional strategies [8] suggested to apply overlay multicast scheme directly to distribute consecutive live media to WLAN users, which is not a good way with the consideration of limited shared bandwidth in WLAN. One simple experiment is designed: building a WLAN with ten nodes, one of which requests media from content provider, out of the WLAN. All ten nodes share media data with N partners. For the purpose of discussing, N will be set 3, 4 and 5, respectively. Bandwidth of AP is 11 Mbps and media data rate is 200 kbps, 300 kbps, 400 kbps and 500 kbps.

Then the average playback continuity (the number of segments that arrive before playback deadlines over the total number of the segments) in different situations is showed in Figure 1.

Figure 1 plots playback continuity against streaming rate, where we contrast this performance in different number of neighbors. When the streaming rate or the number of neighbors is increasing, the playback continuity is degraded. There is one important reason: all increasing connections between peers are sharing the limited 11 Mbps bandwidth. Too many connections will cause traffic congestion in one shared bandwidth and decrease the quality of streaming transmitting finally. The simple experiment shows us that mesh-based P2P overlay multicast will decrease the bandwidth efficiency and quality of streaming in WLAN. According to the above analysis, although tree-based P2P overlay multicast will create little media data connections to share streaming services and outperform the mesh-based one, it still causes traffic congestion and cannot meet the dynamic constraints.

From the above discussions, pure P2P overlay multicast scheme cannot work in mobile and ubiquitous network. Hereby, a hybrid framework is proposed in the paper to distribute live streaming services into wire and wireless network. In every WLAN, one peer with good performances, including online time length, will be elected as multicast agent. Peers of wire network and agents elected from WLAN will be organized into one P2P overlay multicast structure. Every multicast agent will request media data from the outside P2P overlay on application layer and broadcast media data into one registered multicast group in WLAN on IP layer. One agent peer joins the application layer multicast structure and requests media data, which can ensure services reliably. In WLAN, one agent peer sends media data into one IP-layer multicast group, which can save limited shared bandwidth and decrease the traffic congestion. Based on our previous real P2P live streaming system AnySee [11], we have designed and implemented a prototype, named AnySee-Mobile, to support streaming media not only in wire networks, but also in mobile and ubiquitous environment. In contrast with traditional streaming schemes in mobile environments, simulations show that this new system can improve quality of services, including playback continuity.

The rest of this paper is organized as follows. Section 2 discusses the related work. Section 3 presents the framework to support streaming in wire and wireless network. Section 4 describes main algorithms, protocols and technologies. Section 5 describes our simulation methodology and performance analysis. We conclude this work in Section 6.

2 RELATED WORKS

First, we survey the overlay multicast schemes. The most important issue of such schemes is to design a streaming overlay with high service quality and good scalability. In general, there are two types of schemes for optimizing live streaming overlays: tree-based and mesh-based overlays. Borrowing ideas from IP multicast, tree-based protocols, such as ESM, ALMI [4], NICE [6], are simple and easy to implement. The main target of tree-based approach is to construct overlay spanning trees directly, that is, members explicitly select their parents from the members they know. In mesh-based [14, 15] protocols, peers accept media data from multiple "parents", such as Coolstreaming [3], PROMISE [5] and GNUStream [7], ZigZag [12], P2Cast [13], SplitStream [16].

Second, we survey the live streaming approaches in mobile and ubiquitous environment [8]. The mobile multicast proxy scheme provided an idea that the proxy's clients do not need participate directly in the multicast tree or mesh. The multicast proxy joins the multicast tree formation for the peers which its clients belong to. Thus, a multicast proxy plays a similar function to a designated router; however, the multicast proxy also can not be in the member's sub-network and can relay multicast information to the receiver only using unicast, multicast. It also provides for primary and secondary multicast proxies, where a secondary proxy is located closer to the mobile clients, but both primary and secondary proxies can communicate using unicast or multicast tunnels. In [9], mobile multicast (MOM) provides a mobility scheme for multicasting multimedia streams for wide area networking and adopts a wireless IP address based scheme. This paper suggests dealing with the problem in bidirectional tunneling of delivering multiple copies of the same multicast packet to a foreign network. In this scheme, one node, HA, will be elected to route multicast packets to an outside network. Range-based MOM takes the approach [10] one step further and selects a multicast agent close to another node, FA, to tunnel multicasting packets to the outside network.

Up to now, there are little researches and products, which focus on the live streaming services in mobile and wired mixed environments. It is obviously wrong to push P2P technology into mobile network directly; however, conversely, live streaming services can be deployed into mobile devices. In this paper, we can move P2P live streaming into mobile environment. The key problem is not the P2P, but how to link P2P wired network and unstable WLAN with low bandwidth.

3 ANYSEE-MOBILE: HYBRID LIVE STREAMING FRAMEWORK

There are two main parts in this hybrid live streaming framework, including mesh-based overlay as the backbone topology for streaming services and IP-layer multicast structure in wireless sub-network. Considering the heterogeneity, dynamics of peers, mesh-based overlay is appropriate to meet these constraints because there are more than one neighbors as media data provider for every peer. We use peer random selection algorithm to build mesh-based overlay, as described in DONET [1] in simulations and prototypes. Another part is IP-layer multicast scheme.

From examples in Section 1, there are two main points, which should be considered when designing a streaming system based on WLAN mode:

1. normally, bandwidth of 802.11b/g based WLAN is 11 Mbps or 54 Mbps. Physical links are in sharing mode and have congestions when transferring data in these

environments. Here traditional P2P schemes based on unicast will also bring broadcasting traffics in WLAN;

2. mobile equipments can roam among multiple wireless networks. Signals changing when roaming will make mobile equipments join in or quit from WLAN frequently. These behaviors of nodes will bring great impact on the data transferring efficiency.

Considering these two issues, multicast scheme based on IP layer in a single WLAN can be adopted. Based on IP-multicast tunnel, multicast sources can send media data to all destinations for only one time on the physical links.

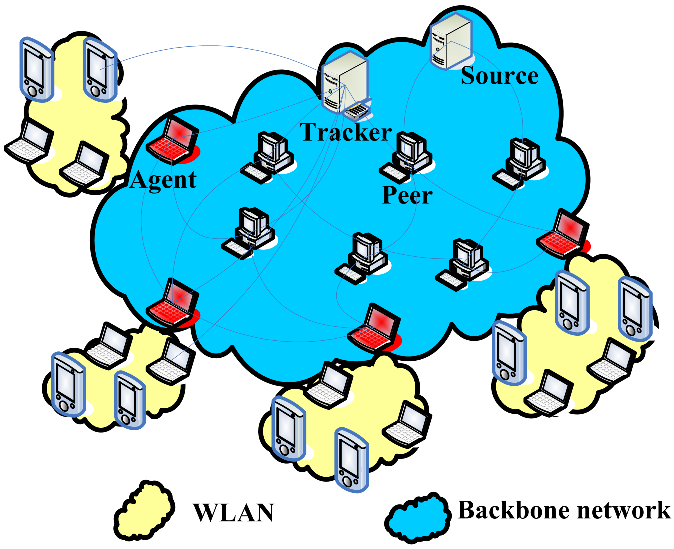

Fig. 2. Framework of hybrid live streaming system

Figure 2 shows the architecture of hybrid live streaming system. In mesh-based overlay structure, there are: one media data source (also named broadcaster in the paper); one tracker server to record information of part of peers; peer, normal node to request media data and share with others; agent, one selected mobile peer to request media data as one normal peer, and to broadcast media as multicast agent in WLAN. Other mobile equipments in the WLAN sub-network of Figure 2 are wireless peers, which join multicast group initiated by agent peer and receive media.

In the design of the hybrid live streaming framework, we focus on the algorithms, protocols and schemes about WLAN, not the architecture of the P2P based backbone network. There is one open issue, which should be considered: how to manage the multicast group, including how to select one wireless peer as multicast agent and how to manage the multicast agent.

4 MULTICAST GROUP MANAGEMENT

The principles to elect multicast agent are as follows:

1. no central point can make the decisions about which one peer can be agent;
2. peers with powerful abilities and good behaviors can be the candidates of an agent;
3. one multicast agent can leave or rejoin the wireless network independently.

One wireless peer will first compute its buffer LSN and services ability. Buffer LSN means the least slot number in buffer windows of the wireless peer, which shows how old the buffered media data is. Serviceability of one peer means the signal intensity in wireless network. Serviceability will change with the peer's moving and with occurrences of other unpredictable events. Containing these two parameters, the peer then sends out one Heart Beat (HB) packet to the multicast address, which has been assigned by the tracker server when the live streaming channel is being built. Then, when the wireless peer receives HB packets initiated by other wireless peers, one competition algorithm to elect the multicast agent will be called. When one peer guesses that it can be a multicast agent, it will send out a claiming letter to all of other peers.

4.1 Buffer Windows Design

Wireless peers have two ways to request media data, namely pulling media from P2P network as multicast agent and pushing data packets to wireless network as normal mobile peer. Then, one important issue is how to manage the buffer windows of peers.

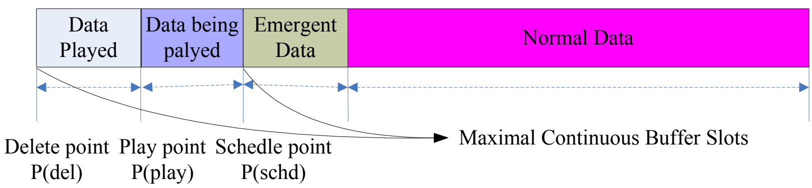

Fig. 3. Buffer windows of one wireless peer

Figure 3 shows the buffer window of one normal wireless peer. In its buffer window, there are four logical parts:

1. data player part: this part records media data, which has been played, but is still buffered;
2. data being played part: this part records media data, which has been requested and is being played;

3. emergent data part: this part records media data, which has not been requested, but is emergent and will be played;
4. the last part, normal data, is still empty and will be requested in the future.

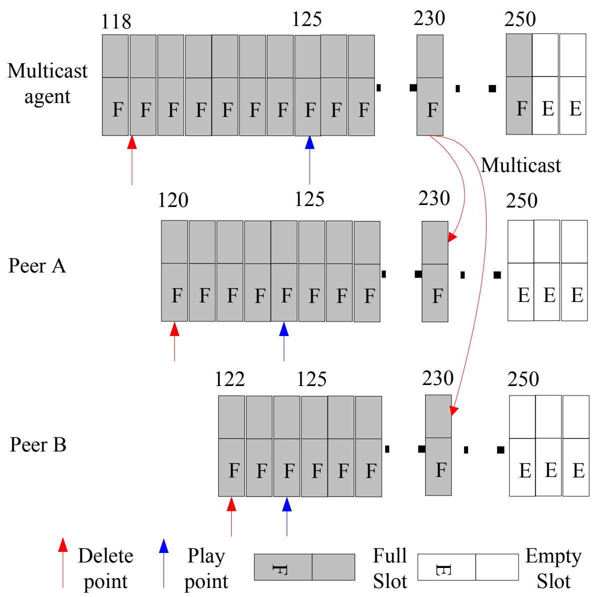

Fig. 4. Buffers of three peers

Figure 4 shows a snapshot of peers buffers at one time point. In Figure 4, there are three peers, including multicast agent and two normal mobile peers. From the figure, multicast agent is sending media data packet, numbered 230, to the multicast address. All normal mobile peers are receiving the packet.

4.2 HB Packet

When peers can compute the buffer LSN and serviceability, the HB packet is important. One normal peer first sets a competition factor, W, to represent the integrated ability of one peer. The competition factor and other information, such as peer address, will be encapsulated into one packet, named Heart beat packet (HB packet).

One HB packet includes five parts:

1. GUID, the exclusive ID number for one peer;
2. W, the competition factor;
3. GUID of agent hypothetically;
4. LSN, the least slot number in the buffer window;

5. flag of agent, zero means the peer is not an agent.

Low latency and high bandwidth are always desirable in streaming services. Due to the fact that all peers in our system are in the same CERNET, so the physical network map is known, and the distance among pairs of peers can be easily computed by the IP addresses. Hence, our system requires each peer maintain a network coordinate database (INCD), such that every peer has a position, named GUID. The GUID value of an end host is a 128-bits integer encoded by the 4-layer geometrical information corresponding to ISPs, cities, campuses, and buildings, respectively. With the help of the GUID based scheme, a peer can find closer peers to build connections instead of randomly selecting neighbors.

Here, we set a W_s , which means the signal intensity and network conditions, a W_{lsn}, which means the good impact from the low LSN. Then we have

$$W = \alpha W_s + (1 - \alpha) W_{lsn}. \tag{1}$$

In the above formula, α is the factor. And we have,

$$W_{lsn} = \begin{cases} \frac{\sum_{i=0}^{N}(LSN_0 - LSN_i)}{\sum_{i=0}^{N}|LSN_0 - LSN_i|} & : \quad |LSN_0 - LSN_i| \neq 0 \\ 0 & : \quad else \end{cases} \tag{2}$$

In one period, the peer A will select one best agent, for example peer B, with the help of all the HB packets from other peers. Then, the peer A can compute the time peer B is elected as agent by other peers. We set W_s as the time. Then, based on Equations (2) and (1), we can compute the competition factor W.

4.3 Election Algorithm of Wireless Multicast Agent

Based on the above descriptions, we can give out our election algorithm of multicast agent. The basic operations are the comparisons between the peer A's competition factor W and other peers' W. There are three situations.

First, if Peer A is already a multicast agent, we should find out whether there is a peer, whose competition factor is bigger than W of peer A, in the WLAN. If there is no such a peer, peer A is still the agent until its next tenure is over. If there is such a peer B, whose competition factor W is larger than that of that of peer A, we will finish the following actions: peer A will check whether its tenure is over. If the tenure is over, peer A should send out a message to B with the following content: "agent wants to be a normal peer". When B receives the message and sends back an ACK signal, then A can leave its position and send out broadcasting message to the multicast address "I am not an agent, B is a new agent", and then acts as a normal peer. Before peer B sends back the ACK signal, peer A is still an agent. The tenure checking operations are necessary to avoid replacing agents frequently.

Second, if peer A is not a multicast agent, peer A will check whether there is a peer B and its competition factor is larger than that of peer A. If there is such a peer B, A is still a normal peer. If there is no such a peer, then peer A will finish the following actions: if there is an agent in the HB packet, peer A will notify the agent with the message "a normal peer wants to be an agent" and waits for the response from the agent. If the response shows that the agent is still in its tenure, peer A will give up. Otherwise, it will be a new agent and notifies all other peers in the WLAN. If there is no agent in the HB packet, then peer A also will be an agent.

At last, if the competition factor of peer A is the same as that of one peer in the HB packet, peer A will give up to avoid replacing agents frequently.

5 SIMULATIONS

5.1 Experimentation Environment

We have built a testing environment: 9 desktop computers act as one tracker server, one media streaming source server (BC), four wired peers and two wireless peers with wireless network card to request media services. Two mobile devices act as wireless peers with operating system, windows mobile 5.0, to join multicast group. In WLAN, there is 11 Mbps shared network bandwidth (according to simulations, the peak bandwidth is 700 KBps). The media source is an ASF file with 378 Kbps bit rates, 4 185 KB size and 343 seconds. Buffer length for each peer is 160 seconds, about 800 slots in buffer window.

5.2 Experimentations Results

Bandwidth consumption means the wireless bandwidth consumption, which can plot the stability and scalability of a hybrid system. Low bandwidth consumption means the efficiency of wireless bandwidth is high and the system has good scalability. To display the importance of multicast schemes, we have set two situations: one has no multicast scheme, just distributes media from the agent with unicast; the other has multicast scheme.

Figures 5, 6, 7 plot the bandwidth consumption when unicast or multicast scheme is used. From Figure 5, five wireless peers exchange media data with each other via unicast scheme, which consumed almost half peak value of wireless bandwidth; however, Figures 6 and 7 show the used bandwidths of normal wireless peer and agent peer when multicast scheme is used. For normal wireless peer, it used only about 50 KBps and the agent used about 150 KBps. It is obvious that the bandwidth consumption is low when multicast scheme is used, which means the traffic collisions are also low.

6 CONCLUSIONS

In the paper we have proposed and implemented a hybrid P2P live streaming system, AnySee-Mobile, in wired and wireless environments. Based on AnySee, a widespread

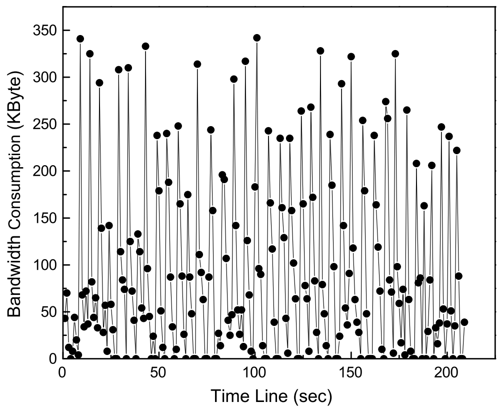

Fig. 5. Bandwidth consumption when unicast

system, one multicast competition scheme has been studied to decrease the links overhead of wireless network and still keep the quality of services. From the experimentations, functions and performances are acceptable. In the future, we will research the layered coding schemes and implement them into AnySee-Mobile system.

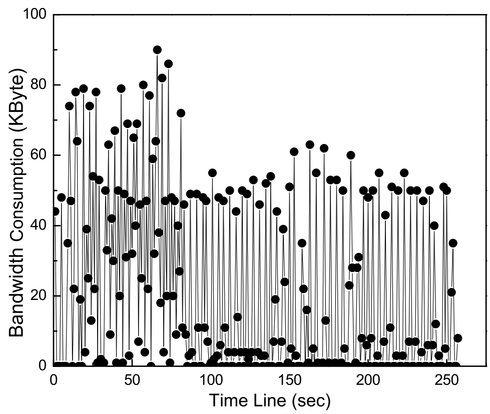

Fig. 6. Bandwidth consumption of normal wireless peer when multicast

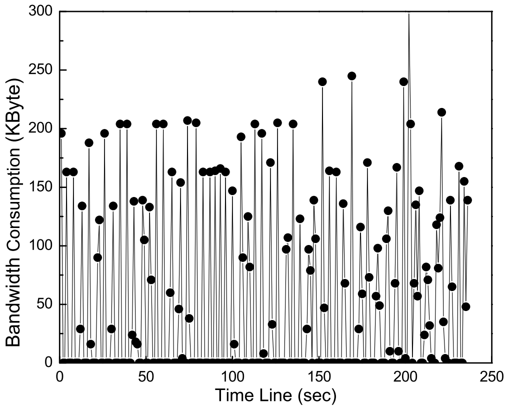

Fig. 7. Bandwidth consumption of agent when multicast

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