RapidStream: P2P Streaming on Android

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Abstract—In this paper we present the architecture of the first mobile P2P streaming prototype for the operating system Android. At first, we discuss the application of P2P streaming in the scenario of mobile networking. Then, the system and software architecture of our prototypical implementation is elaborated. In addition, an initial field test to evaluate the feasibility of the proposed approach is presented. Finally, we report our insights arising from the practical experience with Android.

I. INTRODUCTION

Mobile video traffic is growing rapidly with yearly growth rates of more than 90% according to [2]. The rapid deployment of new multimedia services including video streaming as well as many new video portals, like PPLive, PPStream or SopCast, indicates the evolutionary path towards the next generation of mobile networks. Hence, one important aspect that needs to be investigated is given by the optimal dissemination of video data in the next generation of wireless networks. One viable possibility to distribute the traffic load more evenly in the network and thereby, provide lower costs and higher scalability is given by the usage of peer-to-peer (P2P) technology. However, current P2P applications are not tailored for these new requirements; quite the opposite, P2P streaming applications tend to use the network resources very aggressively and at least P2P streaming applications have no or little preference to exchange data among nearby peers [3].

This is not surprising, because current P2P video streaming applications have been specifically developed for a “wired” scenario, where users run the application at their PC, which is connected via the customer premises network to the ISP. However, with the advent of ubiquitous computing users want to use their accustomed applications wherever they are. Thereby, new requirements arise that need to be addressed by P2P applications in order to provide a sufficient quality of experience.

Let us first clarify the terminology of the P2P domain: Users, so called peers, are connected with each other in overlay networks to share resources, in this case, to disseminate video data. The main difference to the client/server paradigm is given by the fact that each peer can be at the same time client and server. A common approach to disseminate video data via P2P is to split up the data in smaller units, called chunks. They are then distributed between the peers of a swarm. A source node, in this domain called seed, provides the initial upload of the data; subsequently, the downloaders distribute the data further to other peers. To indicate the chunks a peer currently holds, the peers exchange their buffer maps, also called chunk maps. Mainly two different service types can be distinguished within P2P streaming: A video on demand (VoD) system provides users with VCR functionality, e.g. stop, rewind or fast forward of the video. In contrast, by live streaming the users have a more TV-like experience, where all users view the same playback time within a certain range of delay. Regarding the system architecture and, in particular, the implementation of the data dissemination, the systems can be coarsely divided into two main groups: Mesh-pull systems build an unstructured overlay, hence “mesh”, and each peer requests, i.e. “pulls”, the data from other peers. Tree-push systems explicitly construct a dissemination overlay and push the data along the constructed “trees”.

P2P streaming applications have attracted a lot of attention in recent years. Numerous scientific studies investigated their properties, large research projects have been founded to develop prototypes (e.g. NapaWine[12] or PPNext[13]), but more important, real systems have also been deployed successfully. These P2P streaming applications are able to serve simultaneously up to hundreds of thousands of users nowadays. It is therefore just a matter of time when these applications also pervade mobile networks. The goal of our work is to investigate these necessary adaptations of P2P techniques for the mobile, wireless dissemination of video content. For this purpose, we have developed the prototypical P2P streaming application RapidStream. In this paper we will present its current architecture and report our insights of using Android as a client platform for P2P applications.

II. RELATED WORK

Despite the fact that there is a large amount of scientific studies investigating P2P video streaming, there is relatively little work regarding the usage of P2P streaming applications on mobile devices. The first studies introducing P2P video streaming applications that are able to operate on mobile devices are presented by Venot and Yan [14], who introduce a JXTA based P2P video streamer. Yet, their implementation was not able to stream the video content progressively if it was operating on a mobile device, i.e. it could only display the video file when it was completely downloaded. Also Zhang et al. [15] presented a Symbian based P2P video streamer, but the final version of this paper appeared in the 19th International Packet Video Workshop (PV), 2012.
the study did solely evaluate the energy consumption of the proposed system on the mobile devices. Furthermore, Diaz et al. [6] conducted a measurement study on a Symbian based P2P video streaming application over cellular networks. All of these first presented P2P video streaming prototypes for mobile devices suffered from the limited resource capacities of mobile devices given at that time (2007). Only recently by the appearance of much more powerful mobile devices this approach has become feasible in practice. In 2010, Peltotalo et al. [11] presented a fully working RTSP based P2P video streaming application for Nokia smart phones. Other work that investigates certain aspects of this approach consists of Noh et al. [10], who proposed a transcoding scheme to enable video streaming to mobile peers. Cycon et al. [5] introduced a H.264 video encoder that operates in real-time on mobile phones for P2P video conferencing. Finally, Leung and Chan [9] proposed a protocol for the P2P dissemination of multimedia content to mobile devices.

III. RAPIDSTREAM - P2P STREAMING ON MOBILE DEVICES

The migration of P2P video streaming applications to a mobile environment requires certain adoptions, since mobile devices are battery powered and have in general less computing power compared to standard PCs. In addition, P2P applications running in a mobile environment encounter different network dynamics compared to a "wired" scenario. Although next generation mobile networks, like LTE, strive to provide broadband-like downstream capacity, hand-overs and the fluctuating link quality negatively affect the transmission performance of P2P applications [7]. Moreover, the protocols of such P2P applications even increase the rate of control messages due to connection disruptions, and thereby, produce more signaling overhead. Apart from these network induced conditions, there are also new requirements caused by the used hardware platforms. As already mentioned, mobile devices provide less computing resources, i.e. primarily less memory and CPU speed. For instance, on current Android versions the heap space of a Java application is limited per default to a maximum of 32 MB. Only with root access on the device we could increase the heap space to the “hard wired” maximum of 48 MB. As a consequence, this implies that the video buffer must be kept quite small and that it is crucial to hold not too many open connections in parallel. In addition, to enable the P2P video data dissemination on Android, the protocol of the P2P application should be as lean as possible, to avoid too much signaling traffic and in general, to keep the communication overhead at a minimum. Therefore, an important development objective of mobile P2P video streaming applications must be the sustainable usage of the network resources, i.e. to be as energy and resource efficient as possible.

As a platform for our prototype we have chosen Android, which is a partly open source, Linux based OS mainly tailored for mobile devices. User programs written for Android are executed in the Dalvik Virtual Machine (DVM), which is based upon the Java Virtual Machine (JVM). We found that there is generally a good fit between both, but in some cases the Android’s Java implementation provides only stubs and no implementations for some classes of the Java API.

A. System Architecture

For the prototypical implementation we have chosen to build a mesh-pull based live streaming network. Regarding the system design we went for a hybrid P2P overlay maintenance design, i.e. the system is not fully decentralized, since there is a dedicated, centralized infrastructure to retain control of the P2P network and to relieve the load of the peers. The central infrastructure consists of a tracker server, a video server and a rendezvous server. In the simplest case, only a single instance of each component exists in the system. Of course, to increase the reliability and the performance of the system, one could
always use more, redundant instances of each component. The video server needs to register his content at the tracker server to be able to stream video content. In the proposed system, each video results in an own dissemination swarm, i.e. only the peers watching the same video exchange video data. In future extensions more advanced techniques could also be considered to increase the dissemination performance. The process of joining of a swarm, i.e. watching and re-distributing a chosen video, can be described as follows: Upon registration at the tracker server, each peer receives a unique identifier (PeerID). In addition, the tracker server returns a list of the currently broadcasted channels in combination with the connection information of the video servers. If the peer has chosen a video channel, it informs the tracker server of joining the particular swarm. The tracker server supplies the peer with an initial peer list in the bootstrap process. The implementation of the tracker protocol follows closely the standard proposal given in the PPSP Tracker Protocol [4] and it is probably one of the first working implementations. With the help of the rendezvous server, the peer is able to communicate with other peers, even if they or itself are behind a NAT. Right now, only UDP hole punching is implemented, as it yields the highest success rate. However, in future releases we will include TCP hole punching as well to increase the chance of a successful NAT traversal. Upon successful connection setup, the peers exchange their buffer maps and they request missing chunks from each other. The exchange of the buffer maps and the chunk transfer are conducted iteratively as long as the peer is watching the video. Due to the structure of the proposed system, every communication relationship needs a particular type of connection. Figure 1 sketches the system architecture of RapidStream and illustrates the usage of the transport protocols for the different scenarios. For the communication with or between the servers, HTTP is a well suited protocol (as described in [4]), as it is the protocol that is the more likely to work in any case. The communication with the rendezvous server is performed by TCP. The video data dissemination requires a more efficient transport protocol, thus, the connectionless UDP is used. However, to ensure the successful transmission of signaling and control messages between the peers, the framework can use TCP respectively RUDP [1] for this kind of communication too. To ease the performance analysis and the gathering of measurement data, we have also included a statistics server, which receives periodically measurement data from all network participants. Since this server is not a vital part of the P2P network, it is not depicted in the system architecture (cf. Figure 1).

B. Software Architecture

We have developed a general P2P streaming framework, which is based upon a modular software architecture. The framework is purely Java based and can be executed on every Java-capable device. Figure 2 depicts the UML package diagram of the framework. The hierarchical structure illustrates the dependency between the packages. Every package can be easily replaced as long as its dependency is considered. This modular design enables the combination of existing components, it allows for instance the bundling of the tracker server, the video server and the rendezvous server into one executable program. The central Framework-API provides the most common data objects, which are shared between all the modules and which are used for the inter-module communication. After the completion of the framework, the next step included porting the peer module to Android. The architecture of the Android P2P streaming application is illustrated in Figure 3. Porting the application was relatively straightforward; the main difference is that there is no Swing on Android. Therefore, a few GUI classes, in the Android terminology called activities, had to be added to the presentation layer of the P2P videostreamer: The Connection Screen is used to enter the contact information of the different servers, the Video List activity displays the obtained list of available videos and upon reception of enough video data, the Video Player shows the particular video. The brain of the application is the Controller, which manages in coordination with the Streaming Component all the connections through the incoming and outgoing communication modules. The Streaming Component is also responsible for the internal video buffer and for advancing the time line of the chunk buffer.

C. Interaction Pattern of a Peer

Figure 4 depicts an UML sequence diagram that illustrates the initial operations of a peer without explicit error handling considerations. At first, the device running RapidStream connects to the tracker server receiving its PeerID. With the PeerID and its connection information it registers itself at the rendezvous server and requests the list of video servers from the tracker server. Then, the peer may contact a particular
video server and request the list of videos/channels. The connection establishment might be enabled by the rendezvous server, if the video server is behind a NAT. Upon choosing a particular video or channel, the video server provides the necessary meta data of the video. This procedure is further explained in Section III-D. Subsequently, the peer requests the buffer map of the video server and sets its initial buffer map accordingly. In addition, the peer informs the tracker server of joining the dissemination swarm of the video and requests a bootstrap list of other peers participating in the same swarm. The following interactions may be conducted iteratively as long as the peer is a member of the video swarm: The peer contacts the video server to update its peer list, then, it chooses a particular chunk to request and a peer and subsequently, tries to establish a connection to the chosen peer. Again, the connection establishment might be enabled by the rendezvous server. After a successful connection, the peer is requesting the buffer map of the second peer and a particular chunk, if the contacted peer possesses a missing chunk. When the peer has successfully downloaded the first chunk, it may itself serve chunk requests of other peers too. One can observe that we have “outsourced” as much of the overlay maintenance functionality as possible to the dedicated network infrastructure. RapidStream even avoids the standard keep-alive message exchanges between the peers to keep the signaling overhead small. The scarce resources of the mobile devices are mainly used for the dissemination of video data. From the perspective of requiring a lean and sustainable P2P streaming protocol, large chunk sizes are also necessary to yield a small overhead rate. Otherwise, if the chunks are too small, there is a lot of signaling overhead due to the continuous connection establishments and the necessary negotiations among the peers. However, if the chunk size is chosen too large, the receiver will have to wait longer for the reception of a chunk leading to an increased play back delay. In the presented version of RapidStream we have opted for chunk sizes of up to 2 MB to reduce signaling traffic and the energy consumption by limiting the transmission phases of the air interface (compare with the stepwise increase of the received traffic in 7). As each peer receives data from a multitude of peers, the optimal number of concurrent data transmissions is an important parameter to reduce the resource usage too. Currently, each peer downloads from at most 5 peers in parallel. All of these parameters were chosen according to our experimental investigations, but for the best possible video experience they need to be validated analytically. However, we leave this open for future work.

D. Pitfalls on Android

Android provides a multimedia framework that includes codecs for the most common audio and video formats. We use the MediaPlayer of this API for the play back of the received video data in order to avoid writing our own video player. As one might expect from such a smartphone platform, like Android, the Java implementation of the MediaPlayer should be the same on all the particular devices. However, since the MediaPlayer is relying on native implementations of the video codecs, i.e. C/C++ code provided by the particular device manufacturer, we encountered a different behavior of the MediaPlayer instances with regard to different smartphone manufacturers. In order to get the certification "Android compatible" for a particular device, it must be tested by Google’s Android Compatibility Program. Only in this case, it may participate in the Android ecosystem, e.g. have access to the Android market. Despite this certification process by Google, we encountered serious problems with Samsung devices. The state diagram of Android’s MediaPlayer has been specified by Google (compare [8]). Yet, for reasons that have to be clarified, the method call of prepare() may lead in some cases directly to the state Playback Completed on Samsung devices. According to the state diagram in [8] this transition should not be possible, respectively, it is not allowed. To circumvent this error, our current implementation loops over the prepare()
method until the state Prepare is finally entered. We did not
encounter this nuisance on devices of any other manufacturer.
To be completely independent of such limitations, we would
need to provide our own implementation of a media player
with the related codecs. As such a task was not the focus of our
work, we will wait for a porting of other media players, like
the VLC player, to the Android platform in future versions.

Android (up to version 3) supports the two container for-
mats 3GPP and MPEG-4 (Part 12) for video codecs. The
provided MediaPlayer is even capable to support streaming
with RTP/RTSP. Therefore, the general suitability for live
streaming in the P2P context is, in principle, given. Such an
approach would need an implementation of a RTSP server
on every terminal device. This RTSP server would be used
to “feed” the MediaPlayer with the reassembled video data.
However, we could not find a publicly available Java based
implementation of the RTSP stack. Therefore, we decided
dot to implement the needed RTSP functionality, as this was
not the focus of our work either. Yet, we decided to use the
MediaPlayer after all, as one can rely on the fact that this
player is available by default on every Android compatible
device. To make the MediaPlayer capable of progressive
streaming, the video server needs to manipulate the container
format. Most encoders write the meta data of the MPEG-4
container, called moov atom, at the end of the video file and
therefore, downloading the entire file is required in order for
the MediaPlayer to be able to read the meta data of the video
and start the play back. When the moov atom is relocated
to the front of the file and its offsets are adjusted accordingly,
the MediaPlayer is able to start playing the video, even if the
whole file is not yet available. For this reason, the video server
extracts the moov atom and provides it together with other
meta information (the top-level ftyp atom) to the peers. Upon
joining a particular swarm, the peers downloads at first the
video meta data from the video server and creates a temporary
file to buffer the video data as it is downloaded from the peers.
The initial temporary file is empty apart from the meta data
at the beginning. But it will be continuously filled with the
received chunks, which have to be stored at the right position
of the file. If a certain threshold of received video data is
reached, the video play back starts.

Android is a standardized platform for mobile devices,
therefore, one might anticipate that this fact makes the life
of a developer much simpler. Quite to the contrary, due to the
broad, heterogeneous hardware base of Android compatible
devices, we found that the developer needs to test his applica-
tion on as many different devices as possible to ensure its
functionality.

IV. MEASUREMENT RESULTS OF AN INITIAL FIELD TEST

Since we are especially interested in the performance that
can be achieved in practice, we have evaluated the performance
of RapidStream in the following experiment. To judge the
general feasibility of the proposed system, we have conducted
a small scale test run. Due to the fact that we have only a
very limited number of Android devices, we recruited nine
persons, who posse Android smartphones, to participate in
the test run\(^1\). The resulting hardware base is depicted in Table
I. Unfortunately, most of the participating devices were from
Samsung. This fact is responsible for the relatively long start-
up delays depicted in Figure 6 (a). The start-up delay is the
time between the initial request of the video data and the
time the video playback starts. As already mentioned, our
implementation had to loop over the prepare() method until the
state Prepared was finally reached on Samsung devices. This
circumstance had a negative effect on the start-up delays. Yet,
half of the peers could start watching the video in less than 20
seconds. On the HTC Desire smartphone we even measured
start-up delays of less than 10 seconds, which is a really
promising result. To start our experiment, the participants
had to download and install RapidStream from a web server.
Subsequently, they could enter the P2P network and join
the test swarm. One initial video server provided the open
content film “Big Buck Bunny”\(^2\). This video was encoded
by H.264, a resolution of 320x180 pixels and 24 frames per
second. The movie length is 9.56 min and it has a total
data volume of 61.7 MB. Thus, to watch the video without
disruptions, a device needs at least a download throughput of

\(^1\)A short video of the test run is provided at:
http://www.ktr.uni-bamberg.de/project/rapidstream.html
\(^2\)http://www.bigbuckbunny.org/

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Figure 5. Download Throughput (Test Run)


