A Quantitative Analysis of the State of the Art in Quality Provisioning for Multimedia Services over Next Generation Networks

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ABSTRACT

In this paper, we perform meta-analysis of leading publications in the communication area to dig out the exhausted and least investigated areas within the umbrella of Multimedia quality provisioning. We aggregate the result trends according to an original subject taxonomy, as well as several other relevant classifications (scenario, approach followed, and so on). The main motivation behind this work is to gather information and possibly identify the future research trends on this very important area.

Categories and Subject Descriptors

A.1 [**Introductory and survey**]

General Terms

Documentation; Measurement

Keywords

Multimedia, quality provisioning, meta-analysis, survey

1. INTRODUCTION

Multimedia services, such as video conference, video on demand, live streaming, are expected to become widespread soon over the Internet. Estimates [1] report that in the near future approximately 90% of the traffic would be multimedia contents, specially video. This brings into play quality provisioning as a great challenge in future networks [11].

However, multimedia applications are also very sensitive to a number of requirements. Video packets have stringent delay constraints and are prone to packet losses [2], therefore quality for multimedia and particularly for video contents is a challenging and hot research topic in this era.

We believe there is a strong need for collecting and sorting related work in a organized manner. In this regard, *meta-analysis* [9] is a useful instrument to quantify the weight of different areas and research methodologies. Also, it may be applied to get the directions for future work and dig out the most challenging areas for multimedia quality provisioning.

In this paper, we try to aggregate the result trends for multimedia communications by performing meta-analysis of leading journals, conferences, letters, and magazines to dig out the most and least investigated subjects. We also define a taxonomy of the topics involved in quality provisioning for multimedia. This work enables to gather information in a systematic and comprehensive manner and can be used as a research guideline for upcoming researchers so that they can choose their research direction based on the extensive analysis on the topic and its current and future trends.

Table 1: Subject Area Taxonomy

1	Call Admission Control	7	Packet/Flow Scheduling
2	Cross Layer design	8	Power control
3	Error control	9	Rate Control
4	Mobility management	10	Resource Management
5	Multicast/Broadcast	11	Routing
6	Network management	12	Security

2. THEORETICAL FRAMEWORK

One of the objectives of this research is to develop a taxonomy, based on the literature review, to classify the subject areas where various researchers are investigating quality provisioning for multimedia contents. To this end, several research articles have been reviewed/examined thoroughly and sorted out according to their research methodology, model, and research variables. Based on their in-depth examination, we define a taxonomy as described in Table 1 and detailed in the following subsections.

2.1 Call Admission Control

Call Admission Control is a network strategy to control or limit the number of call connections and avoid network congestion so as to provide quality-of-service (QoS) [7].

2.2 Cross Layer Design

Instead of optimizing the layers independently, which is simple but inefficient, multimedia techniques can be adapted jointly across the protocol stack [11].

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2.3 Error Control

If the transport service is not reliable, multimedia quality cannot be guaranteed. Hence, error control techniques such as Forward Error Correction (FEC), Automatic Retransmission reQuest (ARQ) or their combination known as hybrid ARQ can be employed for multimedia packets [3].

2.4 Mobility Management

Mobility management refers to enabling the user equipment for keeping network connectivity when a device is physically moving and/or its point of attachment changes [10].

2.5 Multicast/Broadcast

The term "broadcast" mainly refers to the distribution of multimedia contents to a wide range of audience or receivers. Various schemes exist, for example, heuristic broadcasting or periodic broadcasting. Application Layer Multicast (ALM) is becoming very interesting when the transmission of multimedia streams to a large number of clients is involved [8].

2.6 Network Management

This concept implies system configuration and network parameter tuning [8], possibly with a higher timescale, e.g., in the deployment phase or with a daily schedule.

2.7 Packet/Flow Scheduling

Scheduling is an important aspect with respect to QoS provisioning [8]. To this end, the special characteristics of queues with multimedia traffic need to be considered [3].

2.8 Power control

This may refer to both controlling the power consumption of the terminals, which may be critical for highly demanding multimedia application, and coordinating the wireless access so as to limit interference [11].

2.9 Rate control

This subject deals with transport layer, for example congestion control within the Transmission Control Protocol (TCP). The challenge is to support multimedia traffic efficiently at this layer by properly controlling the rate of the related flows while still guaranteeing adequate QoE [6].

2.10 Resource Management

Optimizing network allocation and efficiently assigning resources is a challenging task. For time-varying wireless channels, the resource allocation can take advantage of variable channel conditions to enhance the system performance [4].

2.11 Routing

Routing can also play an important role for multimedia traffic [5]. Clearly, congested paths should be avoided, but quality provisioning for real-time traffic is also affected by the reliability and update speed of routing protocols.

2.12 Security

The exchange of digital media may raise issues for the protection of intellectual property rights. Thus, techniques are needed to prevent unauthorized distribution of copyright-protected content as well as its forgery and/or intentional corruption [8].

3. QUANTITATIVE ANALYSIS

Extensive content analysis has been conducted to get the general directions of the research related to *multimedia quality provisioning*. In our investigation, the reviewed articles have been selected from a number of major ACM and IEEE communication journals and conferences for meta-analysis. A total of 190 articles have been found in such conferences and journals pertaining to multimedia quality provisioning from the time period 2006-2010.

Table 2: Scope of the study

1	IEEE Trans. on Multimedia	11%
2	IEEE Trans. on Sys.&Cir. for Video Tech.	4%
3	IEEE Trans. on Wireless Communications	9%
4	IEEE Trans. on Communications	6%
5	IEEE Trans. on Networking	7%
6	IEEE Trans. on Mobile Computing	7%
7	IEEE Journal on Sel. Areas in Commun.	5%
8	IEEE Trans. on Information Theory	1%
9	IEEE Commun. Letters	3%
10	IEEE Globecom	24%
11	IEEE ICME	9%
12	IEEE Infocom	4%
13	ACM Sigcomm	3%
14	ACM Mobicom	3%
15	IEEE Communications Magazine	5%

Table 2 represent the list of selected top ranked publications for this study. All the articles have been reviewed by carrying out detailed content analysis. For each article, the *content analysis* research methodology is adopted, which is defined as "a method of analysis in which text (notes) is systematically examined by identifying and grouping themes and coding, classifying and developing categories." [9]

The frequency of the selected articles from the relevant IEEE journals or conferences is also depicted in Table 2. From this table, it is evident that IEEE Globecom (a conference) and IEEE Transactions on Multimedia (a journal) are ranked higher. This may be due to the fact that IEEE Globecom is the major venue for new trends, and a platform for researchers and practitioners. The high frequency for IEEE Globecom also demonstrate the importance of selected topic in recent and future research trends. The explanation for IEEE Transactions on Multimedia may be instead simply because it focuses on multimedia. For each of the articles, the subject area/topic/theme, research methodology, model, variable and research question have been identified. Further, to perform a deeper analysis, we have also identified the simulation environment or tool(s) used and which layers of the protocol stack are involved in the study.

Various directions are explored in the literature for multimedia quality provisioning, as detailed in Section 2. Fig. 1 shows the amount of research work in each of the subject areas defined above. The fields of Resource Management (allocation/reservation) and packet scheduling appear to be prominent. Instead, error control, mobility management, power control, routing and security have received minor attention in the field of multimedia quality provisioning.

Several research methodologies have been adopted to investigate the aforementioned subjects. According to the classification of [9], they can be subdivided into one of simulation study, mathematical analysis, practical/laboratory testbed, framework description, or field experiments. The

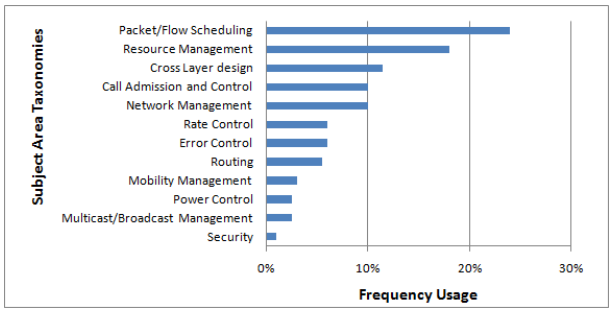

Figure 1: Subject Area Frequencies

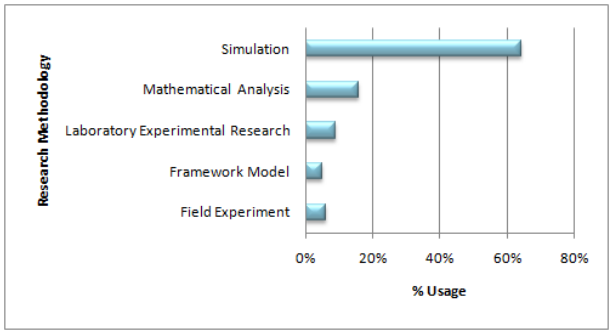

Figure 2: Research Methodologies Usage

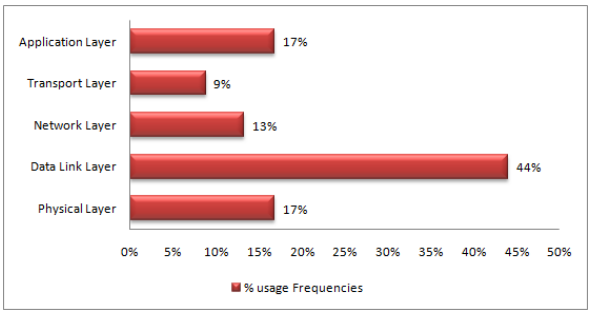

Figure 3: OSI Layer Usage

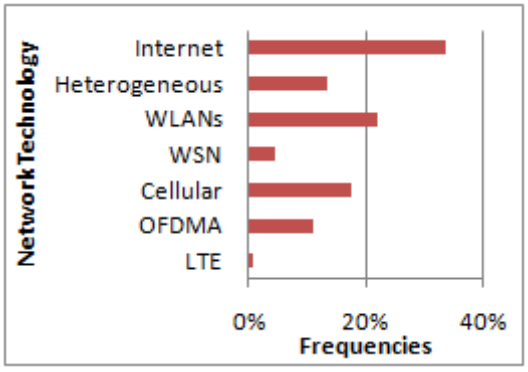

Figure 4: Underlying Network Technology Usage

shares of each research methodology for the considered articles is reported in Fig. 2. It is highlighted how most (64%) of the research in multimedia quality provisioning is based on simulation. The second preferred research methodology is mathematical analysis, which is adopted by 16% of the researchers. Still there are some researchers that use experimentations or real-life evaluations. A relatively smaller, but non-negligible fraction, proposes just framework models, i.e., theoretical discussion without any original proof-of-concept.

Fig. 3 reports instead the frequency of the Open Systems Interconnection (OSI) layers which are considered in the analyzed papers. The classification has been done according to the OSI standard by considering physical, data link, network, transport, and application layers (presentation and session layers have been neglected, as usually done, they have 0 entries anyway). From the figure, it results that most of the investigations on multimedia quality provisioning involve the data link layer, with 44% of the papers. Besides this layer, both application and physical layers are the focus of 17% of the considered papers. Two points are actually worth remarking. The entire classification, and the high frequency of papers investigating layer 2 may be due to the common presence of cross-layer investigations, which therefore involve more than one OSI layer. From these numbers one may infer that cross-layer analysis involving physical layers and medium access control (seen as a part of the data link layer) is fairly common. However, it is surprising that little work deals with intermediate layers, i.e., network and especially transport (only 9% of the papers) layers.

Another classification concerns the underlying technology. Due to the proliferation of standards and communication technologies, multimedia services are currently supported by very variegate and heterogeneous technological supports. We consider here a subdivision driven by medium access control criteria, as layer 2 has been shown in Fig. 3 to be the most explored one. Thus, we distinguish first of all those papers considering Internet-like architectures, also including Local and Wide Area Networks, which are based on the same medium access. For what concerns wireless networks, we distinguish between coordinated access, which either refer to cellular networks, or to other deterministic multiplexing (e.g., OFDMA based, such as WiMax), and contention-based access, which mostly involve WLANs, e.g., based on collision avoidance paradigms. It is worth noting that many papers consider the integration among different technologies; in the case of heterogeneous access the most challenging aspects still resides in the lack of guarantee (or the possibility of providing only soft QoS) in random access techniques. Thus, heterogeneous networks can be considered as a subset of contention-based access. Finally, we consider sensor networks as a separate item; although they may be marginal to multimedia communications, their importance is expected to rise in the close future.

Fig. 4 reports the impact of each kind of technology. About 33% of the research has been performed over Internet-like technologies. However, a large share of papers, 21%, focus on contention-based technologies; observing that also about 14% of the papers consider heterogeneous networks, we may remark that an even larger share than that of Internet-like techniques explores the issue of quality provisioning for WLAN or similar techniques, possibly in combination with others. As expected, the relevance of wireless sensor networks is still limited, only 4% of the papers. Yet, we argue that this value is already significant, given the technological impairments of WSNs compared to other scenarios, and it

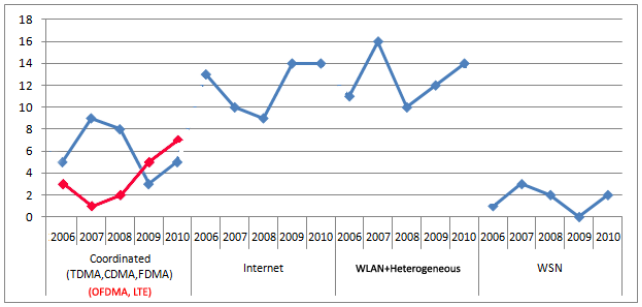

Figure 5: Underlying Network Technology Research Trend

may be expected that this fraction will become even larger, as the papers exploring multimedia over sensor networks are all relatively recent. Finally, coordinated access is investigated in another significant fraction of papers: 17% for cellular networks and 10% for OFDMA (excluding LTE). It is worth mentioning that, although OFDMA-based access techniques represent a significative example of such technologies, only 1% of the papers specifically explore Long Term Evolution networks. Of course, we expect this value to increase dramatically in the next years together with further deployment of LTE networks.

4. DISCUSSION AND FUTURE TREND

Multimedia quality provisioning is a general field, and includes many different research issues. Due to scattered and vast subject areas under the umbrella of multimedia quality provisioning, it is pretty difficult to get a unified view. Therefore, providing QoS for such networks is an open issue and key research area. The major delimitation for this meta-analysis is the scope of the study. A total of 190 research articles have been studied and examined for meta-analysis, but the selected articles are from the top layer journals, conferences, magazine and letters. Such a collection can be considered as a strong suite for this study.

Fig. 5 shows the trend in the number of published papers on multimedia quality provisioning, for each network technology class. Almost everywhere, the interest in multimedia quality provisioning is either increasing or stable. It is also emphasized that in the past years Internet, WLAN and Heterogenous networks have gotten more attention and been investigated more, but the Cellular networks and coordinated access technologies (including TDMA, CDMA, FDMA, and LTE) are now receiving increasing attention. We may argue that the specific trend of OFDMA (highlighted in red) presents a fall and rise behavior which may be due to the shift if interest from WiMax to LTE technologies. Conversely, less attention until now has been paid on WSN with respect to Multimedia quality provisioning; still, we expect an increase for this technology in the next years.

5. CONCLUSIONS

Next Generation Networks are expected to exhibit multimedia contents by 90% as compared to best effort traffic. Thus, multimedia quality provisioning is an important research area in the networking research community. In this paper, we defined a subject taxonomy for such a topic and presented a meta-analysis of the literature. From our quantitative survey, it can be seen that packet scheduling and resource allocation have already been exhausted fields for multimedia quality provisioning in legacy networks; however, the topic is still relevant for OFDMA-based future networks. Conversely, mobility management, error control, power control and rate control are less frequently investigated and can be seen as open directions. In general, the overall research trend for multimedia quality provisioning is increasing day by day, and it is expected that it will increase even more in the future due to the pervasive use of multimedia applications in upcoming network implementations.

We believe that the quantitative evaluations performed by this paper may highlight the existing trend and give guidance to researchers and practitioners, offering a reference value to understand the directions that the scientific community is currently pursuing.

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