A Novel Concept for Hybrid Quality Improvements in Consumer Networks

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***Abstract*—Consumer networks face the problem of lacking quality awareness. The quality of network connections is a problem, as well as consumers are overstained finding quality content of interest. The system proposed in this paper assures the quality of both aspects. We introduce a novel self-organised QoS system and integrate a hybrid personalised recommendation system, managed by a novel Internet router. We show that these features are the key issues to increase the quality of experience in consumer networks dramatically.**

I. Introduction

In this paper we publish our preliminary results from the research project called "Holistic Solutions for Multimedia Systems in Buildings". This project aims on providing hybrid quality improvements for home networks. For this a home gateway router is being developed, targeted for the consumer market. The term "hybrid quality" should be understood in a multimedia-based way. Quality means on one hand the quality of digital media content delivery, called Quality of Service (QoS), but on the other hand also the quality of multimedia content offering, called personalised recommendations. Hybrid means for QoS a seamless bandwidth reservation scheme for mixed wired and wireless networks. For recommendations, hybrid means personalised recommendations from mixed media sources like broadcast (DVB), broadband (IPTV) and on-demand. All this functionality is provided and distributed by a novel consumer router, which manages the QoS as well as the recommendation functionality.

A. Problem Statement

In a home environment with a lot of consumer electronics, we have identified the following two quality problems:

First, the structure of consumer's home networks is chaotic and unpredictable. Novel networking technology like PowerLAN, PoF and Wi-Fi are preferred by customers, since installation effort and connectivity ranges are advantageous for them. But, especially PowerLAN and Wi-Fi connections show dramatic performance breakdowns, when multiple clients are streaming real-time traffic simultaneously. At the same time QoS functionality is not well established in consumer home networks. Some router manufacturer also have recognised this gap and equipped their products with QoS functionality. But either, they support only manual configuration, which overstraines most customers or, if autonomous configuration is provided, prioritisation and resource reservation is only provided by the router, which causes resource blocking in the whole network. Also, traffic inside the LAN can't be controlled by such routers. Therefore, a QoS scheme is needed, which provides self-organised resource reservation on a per link basis, to enable multiple real-time streams protected by reservations on their route through the network.

Second, the service offering from digital media sources is increasing dramatically. Nowadays, not only thousands of broadcast channels are available, also the emerging IPTV and on-demand Internet platforms offer billions of video clips, movies and series. It is impossible for end-users to have an overview about all available sources and to manually find content of personal interest. The same way as in former times, today's customers prefer a comfortable entertainment system, when sparing time for digital media consume. Even entering wishes to search engines can be a too high threshold to against their mentality. Therefore, a portal is needed, which provides individual, personalised and hybrid recommendations from all available media sources to provide the end-user with content he/she likes. Our solution for this is presented in Figure 1.

II. Related Work

In this section we briefly describe the related work in the areas of QoS and personalised recommendation systems. To our knowledge these both topics haven't been researched in conjunction so far.

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Fig. 1. Personal Program Guide

A. Quality of Service

Nowadays, QoS in home networks is provided by home gateways, which provide only a minimum of QoS functionality. Most Internet routers for consumer networks only support manual prioritisation configuration for predefined ports, protocols or applications. The most advanced available technology in state of the art home gateways is the StreamEngine [1]. This technology also provides self organised QoS configuration, but only for the router and no resource reservation, but prioritisation and shaping.

The importance of QoS awareness and QoS user reporting was shown by Desney et al. [2], who built a system called Kermit, which reports the actual connection speed and QoS status to the user and allows for manual configuration of traffic shaping for clients occupying too much bandwidth. They also performed end-user tests in a number of households. These tests included surveys, which where filled by end-users. The evaluation showed that QoS is an important topic for home networks, even if the users have no technical background.

B. Personalised Recommendations

Basically, recommendations can be created by using the content-based filtering or the collaborative filtering approach. The content-based approach filters data, which describe the content in more detail [3], e.g. title, genre, etc. The collaborative filtering approach compares user profiles from the community [4].

The paper from Manuela I. Martin-Vicente et al. [5] presents a semantic approach that builds implicit trust networks, which are applied in collaborative recommendation systems. The used approach obtains trust relations from a record of results by considering previous recommendations respectively by exploiting the interaction with the system. This paper uses a lot of information from users, which is needed to build the relations between users. In contrast to this paper, the presented approach in our paper needs only the specified DVB Service Information.

Ana Belen Barragans Martinez et al. [6] propose a hybrid recommendation system, which considers content-based recommendations and collaborative filtering algorithms. The authors use the Singular Value Decomposition (SVD) for reducing the dimensions of the user-item matrix. The user profiles are created by a social network and users were asked to set the recommendations in an explicit manner. In addition, the system observes the behaviour in an implicit manner. The calculation of the similarities is realised by using the Cosine Similarity. In contrast to this paper, our approach uses a selection of multiple collaborative filtering algorithms.

Besides these approaches, our paper combines linear DVB content and non-linear video-on-demand content. To our knowledge this combination has not been realised before.

III. Approach

A. Quality of Service for Local Area Networks

The QoSiLAN concept [7] is used as a basis for the hybrid QoS strategies. It provides QoS for LANs, which doesn't have native support. It's an approach for collaborative, self-organised QoS in hybrid in-house networks, as shown in Figure 2. QoS is achieved, in contrast to traditional solutions, not by enforcing reservations in the network by switching or routing devices, but by collaborative managing the hosts in the network to avoid disturbing traffic at its source. This requires a set of novel autonomous LAN management techniques.

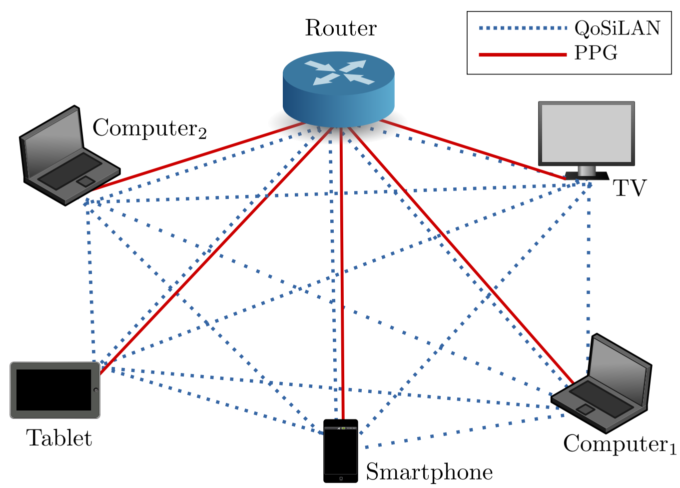

Fig. 2. QoS and Recommendation Communication

1) Analysis of the network topology: For efficient LAN QoS management the physical network topology must be known. Hence, the topology discovery is realised by our own implementation of the Link Layer Topology Discovery (LLTD) protocol [8]. The LLTD protocol discovers the layer 2 topology in LANs. It makes use of the switch's address learning and switching capability. One host in the network, the mapper, enforces other hosts, the responders, to send packets with spoofed MAC-addresses to other responders to probe and evaluate the MAC-address tables of the layer 2 switches. Then, the mapper queries the information of which host has seen which packets to deduct on which host is connected to which switch and to find out in which way the switches are connected within each other. From the gathered topology information, the capacity of the links is tested by active probing between the hosts. In addition, the traffic situation is monitored continuously by all hosts in the network.

2) QoSiLAN Management: The QoSiLAN manager is one host in the network, which maps the topology and gathers all traffic information from the cooperating host. In our case we designed the router as QoSiLAN manager, as shown in Figure 2. This enables us to monitor also in- and outgoing traffic from and to the Internet and also to take hosts into account, which don't support QoSiLAN directly. Since Internet traffic from uncooperative hosts can be monitored by the router the QoS policies can be applied to it. The QoSiLAN manager holds the QoS policies and controls the resources in the network with support from the other hosts. For self-organised management, also autonomous traffic classification is needed. This provides application independent resource reservation functionality.

3) Network Protocol Identification and Classification: The classification feature is realised on basis of an efficient implementation [9] of the Statistical Protocol IDentification (SPID) algorithm [10]. It's a statistical approach to identify network protocols and works in three steps: At first all packets must be grouped together to bi-directional flows according to their 5-tupel. When a flow reaches a minimum number of 20 packets it becomes subject of the actual analysis. The analysis includes 12 statistical measurements like a byte-frequency in the payload, direction-changes of the flow, payload entropy, byte pairs reoccurring and some more. After the analysis it branches into identification or learning. The identification is the heart of the SPID algorithm. It compares the probabilities of the trained flows (Q) with the observed flows (P) by calculating the Kullback-Leibler divergence [11] (KLD), as shown in Equation (1).

$$D(P||Q) = KL(P,Q) = \sum_{x \in X} P(x) \log_2 \frac{P(x)}{Q(x)} \qquad (1)$$

This approach has several advantages compared to the state of the art identification algorithms like Deep-Packet-Inspection (DPI). The SPID algorithms is a privacy-preserving approach, since it only takes statistical measurements of the payload. There is no need for human intervention to analyse the application and to create an unique application signature. Finally, with this approach it is possible to identify and classify network protocols in near real-time with a high accuracy and stability.

4) Bandwidth Reservation and Traffic Shaping: Since as much as possible hosts in the network need to collaborate in the QoSiLAN system to enforce QoS in the LAN efficiently, an appropriate signalling protocol is needed. For this a novel QoS protocol was designed, according to the latest IETF recommendations within the Next Steps in Signalling (NSIS) framework [12]. We developed a protocol, derived from the NSIS Signalling Layer Protocol for Quality of Service (NSLP-QoS) [12], which was adapted to support the peer-to-peer (P2P) collaborative approach, rather than the common hierarchical, router based IntServ approach. Hence, all resource reservation requests are aligned within all co-operating hosts in the network to ensure a maximum QoS for bandwidth reservations. To give a better understanding of

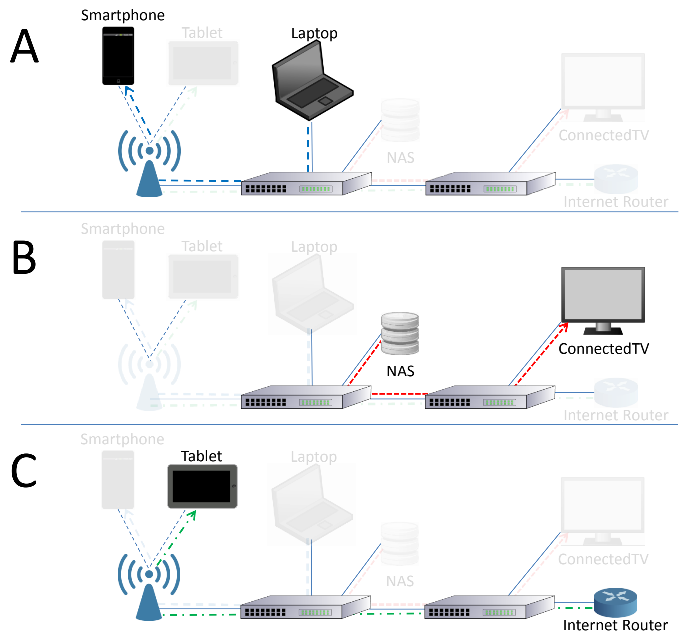

Fig. 3. QoSiLAN Reservation Scenario

QoSiLAN's mode of operation, the scenario in Figure 3 is shown. There, in A a high definition video stream between the laptop and the smart phone is recognised by the QoSiLAN's monitoring module at the sending host, the laptop. The laptop then requests the QoSiLAN manager, the router, to reserve the measured bandwidth of the video stream in the network for the used links. The QoSiLAN manager accomplishes this by sending bandwidth reservation requests to all host in the network. Since the QoSiLAN manager knows the topology and the bandwidth reservation is enforced by traffic shaping in the network's hosts at layer 3, hybrid resource reservation across fixed and wireless networks is possible. The reservation requests are created for each host individually and describe the used links and the maximum allowed bandwidth. Then, in B the connected TV also requests an high definition video stream from the Network Attached Storage (NAS) device. Since the stream in A and B don't share the same links, reservations for both can be set up independently. In C a tablet device requests some content from the Internet. The active reservation states for A and B trigger the router to shape the new content to the residual bandwidth of the bottleneck link on the LAN route to the tablet. In case the router identifies some high priority content, the QoSiLAN manager would have to decide if there is enough residual capacity on the route to establish a new reservation state, or if there are not enough resources, the end-device will receive a message, describing the problem in an user friendly way, giving the user hints to resolve the QoS issue. For this, e.g. the topology map is visualised showing the current reservations with the bottleneck marked. A traffic light meter informs the users about it's current connection speed and the QoS status.

B. Hybrid Personalised Recommendations for Multimedia Content

The hybrid personalised recommendations are presented by a Personal Program Guide (PPG). This PPG shall help consumers to find contents of interest in less time, without looking over the whole meta-data, which is offered by traditional Electronic Program Guides (EPGs). In addition, the PPG presents linear Digital Video Broadcast (DVB) content and non-linear video clips from video portals like YouTube in a single view, as shown in Figure 1. The features of the PPG include:

- Presenting of recommendations
- Presenting of recommendations for today
- Searching related content to the actual broadcast event
- Adding actual event to the favourites
- Setting preferences

The back-end of the PPG is a recommendation engine, which uses content-based filtering techniques and collaborative filtering algorithms. Content-based filtering techniques use the meta-data from the content and collaborative filtering algorithms use data from the community for the creation of recommendations.

1) Content-Based Filtering: Content-based filtering can be divided into two aspects: explicit filtering and implicit filtering. The explicit filtering is used for the creation of an explicit user profile. The presented PPG offers the opportunity for setting preferences. Each user is able to set genres and sub-genres, which are specified by an ETSI Standard for Service Information [13], by setting stars. Zero stars define that the user hasn't rated the gerne/subgenre/event yet, the stop sign represents no interest in the selected item and five stars represents definite interest in the selected item. These information are used to create the recommendations by using the explicitly created user profile.

The implicit filtering uses data, which is observed by the recommendation engine. The PPG logs the viewing behaviour of each individual user and saves it into the explicit user profile. The used algorithm observes the duration a user watches an event, a genre and a sub-genre. With these information, the system is able to create a Recommendation Index (RI), which is in the range [0;1], where 0 represents no interest and 1 definite interest [3].

The implicit and the explicit user profiles are saved and managed by the router. With this technique users can use their personal user profile on different devices. A user can watch events or rate genres in the living room and will have access to these information in the bed room too. The recommendations are retrieved by the clients from the router, see Figure 2.

2) Collaborative Filtering: These algorithms use the community for the creation of recommendations [4]. A typical example for this are online shops. There, if a consumer selects an article, the shop offers recommendations for other articles, like "Customers Who Bought This Item Also Bought …". The PPG uses data from the whole PPG community. A novel collaborative-filtering system, which includes new developed algorithms enables the PPG to predict recommendations very precisely. In contrast to existing algorithms, the new developed system produces a lower error when calculating predictions. Figure 4 shows the Mean Absolute Error (MAE) of different algorithms of one performed test by considering data from an evaluation [14]. The Figure shows, that in this special case the *Absolute Cosine Similarity* (ACS) produces a lower MAE than the *Pearson-r Correlation* (PC), the *Spearman Rank Correlation* (SP), the *Adjusted Cosine Similarity* (ADCS) and the *Cosine Similarity* (CS).

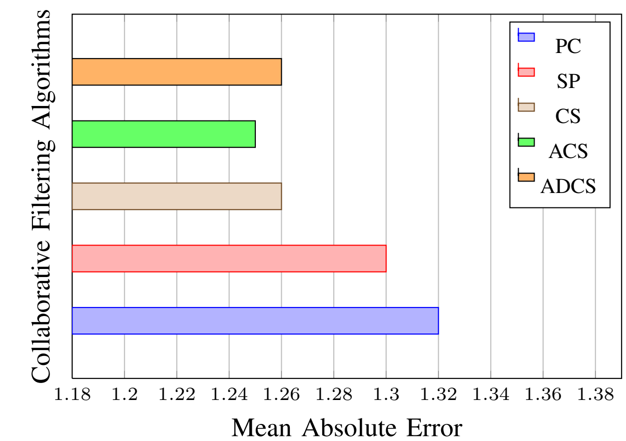

Fig. 4. Mean Absolute Error – Collaborative Filtering Algorithms

C. Router

The novel router is armed with a 800 MHz ARM CPU and runs under an embedded Linux operating system. It serves as QoSiLAN manager and as personalisation profile manager. We evaluated the performance of the SPID algorithm with the new router_B and compared it with another older 200 Mhz router_A model. The results are given in Figure 5. The results revealed that the QoSiLAN system needs such a high-performing hardware platform to classify traffic in real-time. Router_A takes for the identification of a TCP stream from 5 sec to 6 sec. The new router_B takes for a TCP stream classification at maximum 0.06 sec. The results show a vast

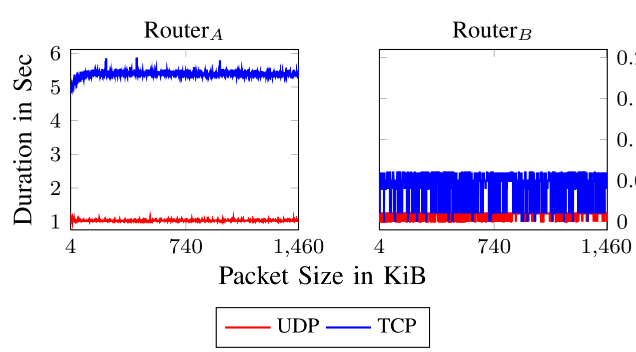

Fig. 5. Router Performance Result Comparison

difference between those two routers. The question that arises here is why does $router_A$ need so long to identify a TCP flow? The answer is in Figure 6, which shows the duration of the identification depending on the number of protocols, which are located in a database. Figure 6 shows, that the

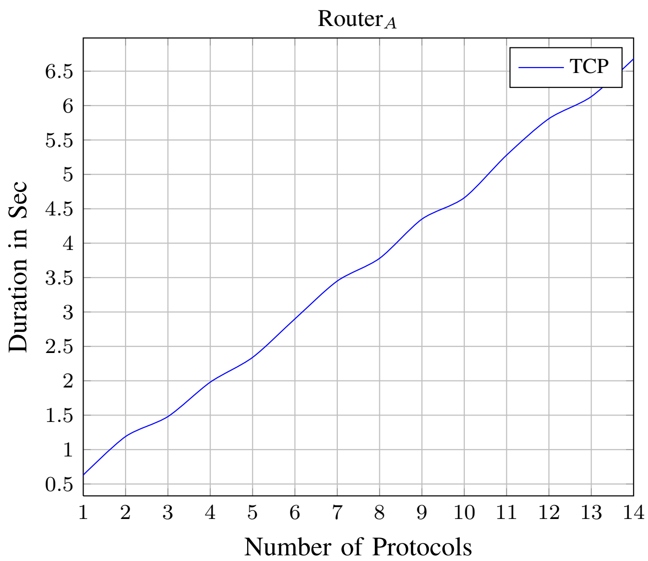

Fig. 6. Performance Result depend on the Number of Protocols

duration is linear to the number of protocols. This means, the more protocols to identify, the more often the KLD must be calculated and the more computing power is needed.

IV. Conclusion and Future Work

The preliminary results, presented in this paper are very promising. The router is able to provide QoS in networks, where this wasn't available before. The outstanding capability is the bandwidth reservation in the LAN, which is not available in consumer networks, yet. Another important consumer aspect is that the QoSiLAN system works without the need for investing in new networking infrastructure hardware. The PPG portal brings more quality in the consumer's user experience, since content of interest is now available at a glance with a very high precision. Hence, the router acts as central quality manager, since it acts as QoSiLAN and content personalisation manager. This idea of quality is the holistic, integrated approach, which brings overall quality of experience to the consumers.

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