QoSiLAN - A Heterogeneous Approach to Quality of Service in Local Area Networks

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***Abstract*—Since most real-time audio and video applications lack Quality of Service (QoS) support and QoS-aware network hardware is not common in consumer grade networks, the Quality of Experience (QoE) of, for example, high definition Internet Protocol Television (IPTV) is very limited. Therefore, this paper proposes a novel approach for enabling QoS in unmanaged, heterogeneous Local Area Networks (LAN) across access technologies. To support QoS in LANs, especially in the home's environment, the QoSiLAN system enables self-organised QoS, implemented in the hosts, rather than modify the protocol stack. In contrast, traditional solutions rely on network support by switches, access points or routers. Per-link resource reservation and prioritisation are achieved by knowledge of the topology map and by reducing the bandwidth of disturbing best effort traffic caused by other communicating hosts. Since QoSiLAN follows a layer 3 QoS model, it qualifies for LANs with mixed access technologies.**

***Keywords*-QoS, heterogeneous LAN, unmanaged networks, topology discovery, traffic analysis, network management.**

I. Introduction

Multimedia streaming services are common in home and private networks and demand will increase further. IPTV and Voice over IP (VoIP) services demand for high bandwidth and have very stringent QoS requirements.

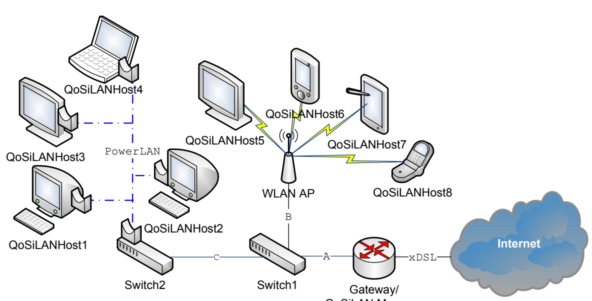

Figure 1. QoSiLAN Heterogeneous Testbed

To guarantee these, common QoS strategies like IntServ, using RSVP, or DiffServ have to be supported by the network. Since most home or private networks use low cost hardware, these technologies aren't usually supported. In Addition unreliable shared medium access technologies like WLAN or PowerLAN are deployed in consumer households. This results in less technology acceptance by users, since lacking QoS leads to a lower QoE level [1]. Especially for IPTV providers the network plane inside the households is unpredictable, as providers can only influence the QoS level to the house, not within it. One approach to increase QoE in LANs is the QoSiLAN system approach, which we proposed as doctoral thesis topic [2] and we present in this paper. It aims to provide a QoS resource reservation solution for heterogeneous unmanaged networks without consistent QoS support as shown for example in Figure 1. In this testbed the QoSiLAN Manager sits between the home network and the wider Internet. The end nodes are connected via different switches, access points and PowerLAN. That way, different nodes may interfere with other nodes on their path and links.

II. Enabling QoS

Current methods for enabling QoS were investigated and compared to our QoSiLAN approach.

A. Related Work

Traditionally, QoS on IP level is realised through IntServ and DiffServ protocols and algorithms, implemented in the router and switch hardware. The most popular protocol enabling IntServ is the RSVP. The IETF proposes a new signalling framework, the Next Steps in Signalling (NSIS) framework [3]. Its first reference protocol is the IntServ NSIS Signalling Layer Protocol for QoS (NSLP QOS) [4]. NSIS is a layered framework to harmonise future signalling protocols to share a common transport layer. NSLP QOS is comparable to RSVP, where applications request resources along the end-to-end data path. It utilises the RSVP research experiences of the past. In RFC4094 [5], the most common resource reservation protocols are analysed. They all have in common that all entities, client and server applications as well as the routers and switches along the path have to support the protocols, whereas the client has to actively request the resources. DiffServ has to be supported by server applications to mark the outgoing packets with DSCP values, which enable the DiffServ supporting routers and switches along the data path to prioritise the packets. However, computing costs and high implementation effort prevented the deployment in low cost consumer network hardware and software. Driven by the common opinion that QoS problems are not present in small scale, fixed 100Mbit/s Ethernet LANs, research to date focused on optimising unreliable shared medium access technologies on physical layer, link layer and cross layers to gain QoS there. Heterogeneous approaches to enable consistent QoS between wired and wireless networks have been proposed. Skyrianoglou *et al.* [6] use the IP header's DSCP value to place the packets in different queues, which requires MAC layer modifications and an additional wireless adaptation layer. The IEEE802.11e standard also defines a mapping between DSCP values and packet prioritisation. Senkindu *et al.* [7] propose a scheme that enables seamless inter working of IEEE 802.11-2007 EDCA MAClayer QoS with wired network IP-layer WRR QoS. They map EDCA ACs to corresponding IP layer traffic classes. This enables classified wireless traffic to receive prioritised QoS on the wired network. This scheme has to be implemented in WLAN-Wire bridges or access points. But most of the research focused on access technology specific solutions. For example modifications of the Ethernet's media access control mechanism, CSMA/CD, used by the 100Mbit Ethernet standard, are proposed by Endemann *et al.* [8]. They modify the length of the TDMA's inter frame gap (IFG) dependent on the packet priority. High priority packets are sent using the minimal IFG, defined by the ethernet standard and packets with lower priority are sent using longer IFGs. The main advantage of this solution is the layer 1 approach, which enables the QoS directly in the medium and guarantees the best QoS, when synchronisation is assured. Although this approach is advantageous, its practical relevance is limited, due to firmware and driver modifications on any connected network interface. Unless manufacturers offer those, the consumers cannot benefit. In addition, home LANs are often equipped with heterogeneous access technologies, where this approach is not applicable. Within the research project HOMEPLANE [9], an approach to address QoS in wireless home networks was developed. Hundt *et. al.* [10] propose the introduction of a home profile for future WLAN standards. This should include a modified interleaver and, additionally, a shortened guard interval of 200n. To minimise radio interference they also propose dynamic frequency hopping. These modifications are part of a cross-layer concept. From a special MIB the collected physical layer data is acquired and interpreted by a resource manager, which controls channel parameters of the physical as well as the link layer. All these QoS technologies have in common that they require infrastructure support. If there isn't any, the protocols or their modifications work transparently without QoS scheduling. If individual LAN segments don't support, the QoS is worse.

B. The QoSiLAN System

The goal for the QoSiLAN system approach is to enable QoS for per-link resource reservations and per-flow packet prioritisation without network support. To archive this the QoSiLAN system combines different core technologies. At first physical network discovery algorithms and QoS parameter tests run through, to generate a detailed map about the local network and its available resources. Second, traffic monitoring, analysis and policing is performed. Finally network resources are reserved and prioritised for the monitored flow, through QoS signalling. As shown in Figures 1 and 2 the QoSiLAN Manager acts as central intelligent entity, which coordinates and admits all resource reservations through signalling. The core piece of the implementation is the QoS policing module, which combines all the information to admit and manage the resources by signalling. The QoSiLAN manager may act as Internet gateway router to enable control of incoming traffic. In contrast to

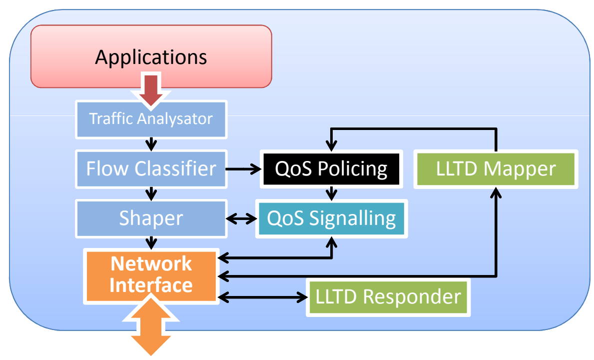

Figure 2. The QoSiLAN Manager Architecture

common QoS strategies QoSiLAN doesn't depend on router and switch support to enable QoS, but in can make use of it, if available. It advises all hosts in the network to shape their traffic according to its policies. The hosts in the network only need to shape or prioritise those traffic flows, whose data-paths affect physical links where current reservations or policies apply. The QoSiLAN Host architecture is shown in Figure 3. Its implementation is much simpler, since the intelligence of the system, the mapping and policing are performed only in the QoSiLAN Manager. The analysis and classification capabilities are also required in the hosts. During real-time traffic identification the flow parameters are sent to the QoSiLAN manager to admit and to enforce the resource reservations. The elements of QoSiLAN are topology discovery, traffic analysis and classification and signalling for resource reservation.

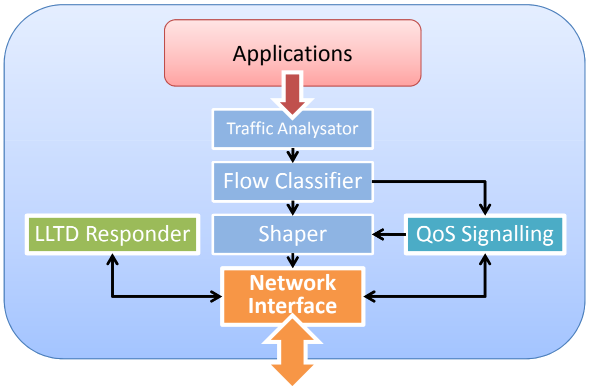

Figure 3. The QoSiLAN Host Architecture

1) Topology Discovery: To discover the physical topology of a LAN, Microsoft's Link Layer Topology Discovery (LLTD) protocol was chosen. It is based on R. Black's [11] connection reasoning technique. The algorithm mainly makes use of probing address tables in layer 2 switches. Hosts send Ethernet packets with spoofed addresses to the network to test the learning capabilities of switches in an intelligent way, so that conclusions can be drawn regarding, which hosts are connected the same or to different switches. The LLTD protocol reveals not only the map of the network, it also enumerates all hosts and gathers many QoS related data like link speed, access technology, addresses, etc. Microsoft's QoS2 API also utilises the LLTD protocol to measure QoS parameters for connections. A self implemented LLTD protocol mapper with additional capabilities is used to map the physical connections of hosts, switches, access points and bridges by active probing. The mapping is performed by the QoSiLAN manager, which acts as trusted central intelligent entity in the LAN. The other hosts in the network need to run an extended LLTD responder daemon, which performs active network probing when demanded, answers to LLTD queries originated by the QoSiLAN manager, and shapes and marks outgoing packets, if necessary. Using additional deep LAN scan techniques hosts, which don't support the QoSiLAN or LLTD protocol are detected.

2) Traffic Analysis and Classification: The QoSiLAN system approach requires traffic analysis on all hosts and the gateway, in the network, since in switched networks only the communicating parties "see" the packet flows. Packets are identified by deep packet inspection using optimised Statistical Protocol IDentification (SPID) [12], which combines several simple statistical meters. The main advantage is the near real-time identification capability. Its trivial mathematics makes it applicable in embedded systems with limited computing capacity. We adapted the SPID algorithm for our purposes and achieved very high detection rates for UDP and TCP traffic, which made it a good choice for the desired purpose [13]. In our first tests, a classification was used based on statical policies, which prioritises real-time traffic. If the gateway router is also QoSiLAN enabled it may also scan the incoming traffic, so that those flows can also be prioritised or resources can be reserved for them within the LAN. In particular, web video applications, which tunnel their streams using HTTP, and are therefore not easily distinguishable from common Internet traffic, can be identified by this method.

3) Signalling for Resource Reservation: The core piece of the QoSiLAN approach is the novel signalling procedure. While present QoS protocols communicate end-to-end and QoS aware network elements are involved, QoSiLAN is different. As shown in Figure 4, one end system (QoSiLAN

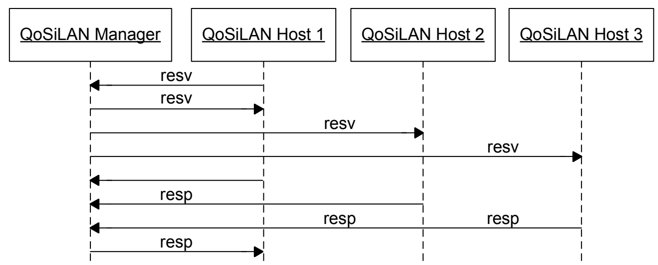

Figure 4. QoSiLAN Signalling

Host 1), preferably the sender of a data flow, informs the local central entity, the QoSiLAN Manager, about the needed resources to request them (resv arrow). This novel approach allows indirect soft-state per-link resource reservations in unmanaged networks. Based on the topology map and using the information of source and destination address for the actual flow, the QoSiLAN Manager creates individual shaping policies for each host, described by destination addresses and maximum bandwidth. Then the gateway sends the sophisticated resource limitation requests to all other hosts in the network to thus achieve a resource reservation for the physical links along the data path. The hosts in the network shape their traffic if their data flow affects links where active reservations apply. Also, clients broadcast informational messages to notify about best effort traffic occupation they cause on links with active reservations. The signalling will be implemented following the NSIS framework and the NSLP QOS message formats. Since QoS on IP-layer can never compete with QoS on layer 2 or 1, the QoSiLAN Manger additionally requests the hosts in the network to DSCP-mark the packets for flows, which are protected by active reservation states. This enhances the QoS if network elements on the route happen to support this type of prioritisation.

4) Limitations: When implemented in the field, the main limitations are likely to come from the hosts, that not allow an implementation of a QoSiLAN daemon. If such a host is sending uncontrolled (non shaped) data to a QoSiLAN enabled host, the receiver may shape the traffic on reception. This may help with TCP traffic, since sliding window control in TCP is possible, but this doesn't apply for UDP traffic. Uncontrolled communication between two not supporting hosts can congest links protected by QoSiLAN reservations. Nevertheless, QoSiLAN reserved flows are marked with DSCP values and might have forwarding priority with QoS aware hardware.

C. Proof of Concept

To evaluate the concept, limited testbed measurements have been carried out. The manually configured testbed was equipped with two video servers and two video clients. Between the clients and the servers a bottleneck connection with 10Mbit/s capacity was placed. As shown in Figure 5a), the two RTP/UDP streams with a CBR of 8440kbit/s conflict at the bottleneck, and each one gets a maximum of circa 5MBit/s bandwidth. This would lead to massive frame

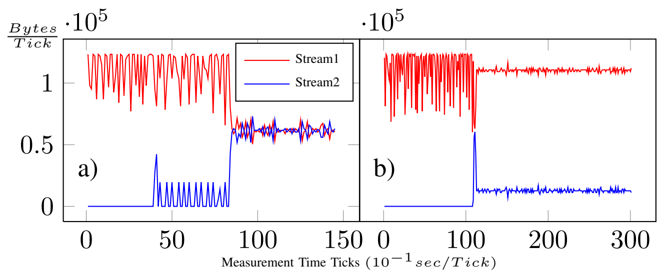

Figure 5. Measurement Results a) Without QoSiLAN Controlled Shaping b) With QoSiLAN Controlled Shaping

dropping and a stuck video stream at the clients. In Figure 5b) Stream1 started first and reserved 8440kBit/s. Therefore, Stream2 is shaped to 1Mbit. It is shown that Stream1 isn't harmed by Stream2 and no frames are dropped. This proves successfully that collaborative bandwidth reservations are effective and an applicable approach to enforce QoS in LANs.

III. Conclusion

Our proposed QoSiLAN system is a novel QoS approach to enable consistent per-link resource reservations, even in heterogeneous networks with mixed access technologies. This collaborative QoS approach is innovative and unique, as it doesn't require support of switches and router. Although final results are not available yet, the expectations on the network performance won't compete with other link or access layer QoS solutions, regarding the maximum network utilisation. In contrast to other solutions, our proposal works for most topology configurations and cross access technologies, especially in home environments. As long as the topology can be mapped, and most of the hosts support the system, QoS can be provided by software, where otherwise expensive hardware is needed. Currently, full testbed system with its different modules is under development. Future research will focus on admission and policing, quantifying the QoS performance against other solutions and optimisation to suit most common consumer topologies and applications.

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