Dynamic Scheduling of Multi-media Streams in Home Automation Systems

(Demo Paper)

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ABSTRACT

A new trend in home automation is to integrate audio en video applications. However in current domotics systems, these are usually conFigured statically. We implemented a home automation tool that dynamically (re)schedules bandwidth for different types of multimedia streams with different constraints toward latency and quality. The dynamic scheduling problem was implemented using distributed agents negotiating for bandwidth using the contract-net negotation protocol.

Categories and Subject Descriptors

H.4 [**Information Systems Applications**]: Miscellaneous; I.2 [**Computing Methodologies**]: Artificial Intelligence—*distributed A.I.*

Keywords

Distributed Scheduling, Negotiation, Audio/Video over IP

1. INTRODUCTION

The use of electronic devices in our daily lives has increased considerably both in our work as in our home environment. These devices help out with solving problems, increase comfort and security, etc. Their functionality varies strongly in their degree of intelligence, autonomity and complexity. A new trend in home automation is to integrate audio en video applications. However in current systems, applications are usually configured statically. A video stream will be configured in a certain format so that the network is not too overloaded. When new applications are started (like for instance a videophone), the chosen configuration will probably not be suitable anymore. Therefore network streams should be configured dynamically. We have implemented a home automation tool that dynamically (re)schedules bandwidth using the multi-agent contractnet negotation protocol (CNP)[3]. This tool is the result of a research project in close collaboration with a home automation software company. The tool is intended to be used in combination with a Contatto home automation system. A Multi-Agent System (MAS) is a natural architecture for modeling such a distributed infrastructure [6]. Autonomous agents can make decisions and execute actions based on uncertain information in order to reach their goals. In group, agents can communicate their intentions and try to cooperate with each other in order to achieve a better usage of shared resources. MAS have proven before to be successful in dynamic distributed scheduling and have been used for developing a wide range of dynamic scheduling applications [2, 5]. Allocating bandwidth to network streams is a dynamic scheduling problem. The capacity and availability of shared resources varies unpredictably. Different network streams need to use the common network resource in an optimal way. The different types of streams have different constraints involving quality and latency. Streams which require high quality can use buffering, while low latency streams have to be scheduled immediately. In the domain of home automation we identified a number of network stream types:

1. multimedia streams require high quality, latency is of less importance;
2. videophone streams require low latency, quality is of less importance;
3. command signals, e.g. turning on the lights, require ultra-low latency;
4. logging services are performed in the background: they have no special demands concerning latency;
5. alarm signals, e.g. phone rings, require ultra-low latency.

The quality of 3-5 cannot be influenced, as it is fixed. This list is non-exhaustive: other types of network streams can be taken into consideration. Figure 1 clearly illustrates the multi-objective character of the scheduling problem. For each network stream quality and latency constraints can be visualised. The objective of the scheduling problem is to maximise quality and to minimise latency of the different streams, while not violating the demanded constraints. In the next section we describe how agents can negotiate bandwidth allocations for the applications they represent, based

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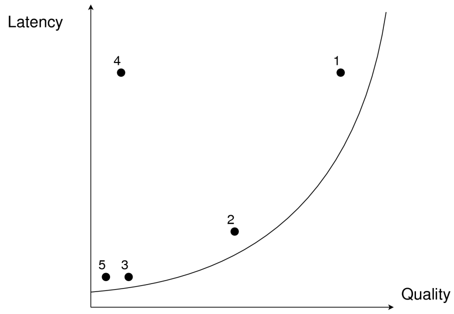

Figure 1: Quality - Latency relation

on suitable utility functions and priority rules. The negotiation is performed according to the contract-net protocol.

2. NEGOTIATING BANDWIDTH

As is the case in the congestion control and resource allocation problem in telecommunication networks, it is important to assure the inhabitants of an automated home some agreed QoS for the heterogeneous types of streams mentionend above. From an engineering point of view, QoS is usually measured by the level of loss, jitter, delay etc. However, as in economic theories, the level of end user satisfaction can also be represented by utility functions. The latter technique is independent of some objective measurements such as packet loss, delay etc. This fits our home automation case study perfectly, since for some data streams the level of for instance delay is important, while for others it is not. Previous studies [1, 4] show that different utility functions can be characterized for different traffic. The so called elastic traffic such as file transfer (ftp, http) or electronic email leads to an increasing, strict concave utility function. On the contrary, real time applications, such as voice-over-IP have non-concave utility functions. As a consequence, in some regions of the bandwidth-utility plot for real-time traffic the bandwidth can be lowered without affecting the level of satisfaction. An example of this is the Fermi-utility function defined in [1] and given in Figure 2(right). In our

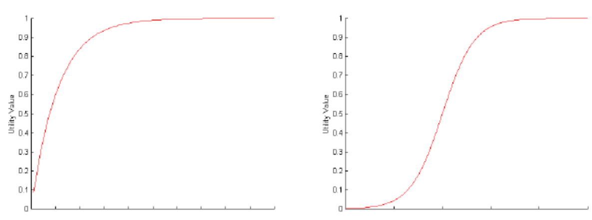

Figure 2: Utility Functions for elastic traffic (left) versus real-time traffic (right) (bandwidth versus utility)

tool, each agent operates according to an utility function that represents the satisfaction level of the stream application it represents. For instance, a video-agent will be responsible for displaying real-time video streams and uses a Fermi-utility function to make decisions on whether or not he can free some bandwidth when the network agent makes a request. In Figure 3 a typical communication scene is displayed between video-agents that are being served, the network agent, which is the coordinator, and a new arriving video agent. The network agents awaits the proposals of the active video agents about how much bandwidth they are willing to turn in. Based upon priority and potential losses the network agent will accept proposals until the new service can be provided and a fair reallocation is made.

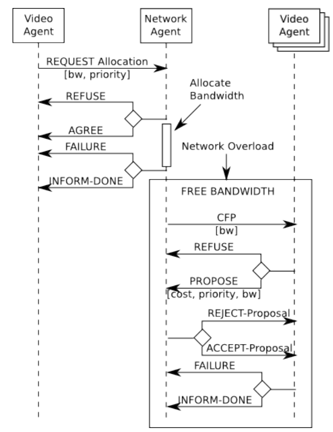

Figure 3: A typical negotiation between video agents, a network agent and a new arriving agent using CNP

3. DEMONSTRATION

In the demonstration we simulate a home situation were concurrently several activities can be started that need bandwidth. Initially bandwidth is sufficiently present and then gradually the network will be more and more overloaded. The tool displays all competing agents and the evolution of the bandwidth that is available to them. The effect of negotiating when newcommers arrive is clearly shown in the evolution of the graphs.

4. ACKNOWLEDGMENTS

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