An Intelligent Video Streaming Technique in Wireless Communications

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Abstract—This paper is concerned with an intelligent application of Moving Picture Expert Group (MPEG) video transmission over a Bluetooth Asynchronous Connection-Less (ACL) link. MPEG Variable Bit Rate (VBR) video is data hungry and presents excessive time delay and data loss over a wireless communication. In a Bluetooth channel transmission rate could also be irregular, due to interferences caused by Bluetooth channel noises or other nearby wireless devices. Therefore, it is difficult to transmit MPEG VBR video over Bluetooth without time delay or data loss. A buffer entitled 'traffic-shaper' is introduced before the Host Controller Interface (HCI) of the Bluetooth protocol stack to prevent excessive overflow of MPEG video data over the network. This paper presents a novel Self-tuning Neuro-Fuzzy (SNF) scheme to monitor the traffic-shaping buffer output rate, in order to make sure the video stream conforms to the traffic conditions of the Bluetooth ACL link. The Matlab-Simulink computer simulation results demonstrate that the use of the SNF control scheme reduces time delay and data loss, as compared with a conventional MPEG VBR video transmission over Bluetooth.

1 Introduction

Moving Picture Expert Group (MPEG) Variable Bit Rate (VBR) encoding scheme is a compression technique, which is preferred by service providers for transmission, as VBR produces a constant image quality. However, MPEG VBR video sources have high bit rates and require a large bandwidth for transmission over a network. Bluetooth networks usually present volatility in various ways. For example, interferences might happen in a Bluetooth network by other wireless devices in the same Industrial, Scientific and Medical (ISM) band or by general Bluetooth channel noises [1]. The data rate is also hampered as a result of data losses due to retransmission and the condition of the device at the reception of the Bluetooth link [2]. Considering these, a novel self-tuning Neuro-Fuzzy (SNF) control scheme is designed for MPEG VBR video transmission over the Bluetooth wireless, which regulates the output bit rate from a traffic-shaper according to the present conditions of the wireless link.

Fuzzy logic and neural networks deal with imprecision and instability inherent in physical systems using natural language, and thus achieve robustness and inexpensive solution cost. In the past, research has been carried out into many applications of fuzzy logic and neural networks to MPEG video and multimedia transmission over wireless networks [3-6]. The computer simulation results demonstrate that the use of the fuzzy logic and neural networks improve quality of multimedia transmission over wireless and also guarantee stability. This paper takes the multimedia transmission research over wireless further by using a novel SNF technique.

2 Development of an intelligent video streaming technique over Bluetooth Wireless

Bluetooth 1.2 provides two types of links – Synchronous Connection Oriented (SCO) link and Asynchronous Connection-Less (ACL) link [7]. The ACL asymmetric bandwidth may support up to 723.2 kb/s downlink using DH5 packets, with 57.6 kb/s uplink. The ACL payload is protected by error checking schemes. When the error checking fails a retransmission takes place, unless the pre-set flush timeout timer expires. In this work an ACL link is utilized for video transmission over a Bluetooth channel. Voice-over-IP (VoIP) technology enables real-time voice to be sent over a data network. VoIP requires and has successfully achieved real-time delivery capabilities. Since Voice/Video-over-IP (VoIP) could send voice as well as video as IP packets, then they could both be regarded as data. The VoIP is on top of the adaptation layer in the Bluetooth protocol stack.

Fig. 1 outlines the overall diagram of a Fuzzy controller and a Self-tuning Neuro-Fuzzy (SNF) controller for MPEG VBR video transmission over a Bluetooth ACL link. As the diagram shows, in this research a traffic-shaper is introduced to manipulate and co-ordinate the VBR encoding video prior entering the Bluetooth channel. The shaper buffer's role is to smooth the video output traffic and to partially eliminate the burstiness of the video stream entering the Bluetooth network. The Fuzzy scheme controls the output rate from the MPEG encoder and the arrival rate at the traffic-shaper, in order to prevent either saturation or starvation of the buffer. The role of the SNF controller is to satisfy two criteria, one to reduce the traffic congestion in the network, and two to uphold constant video image quality. The arrival rate $\boldsymbol{R_a}$ is controlled on a Group-Of-Picture by GOP basis and the departure rate $\boldsymbol{R_d}$ is controlled on a frame by frame basis. The VBR encoding is changed only in critical periods when the shaper buffer threatens to overflow. In this paper, Bluetooth is chosen as a wireless link. However, the idea of rate control according to the link behavior may be applied to any other wireless networks.

A self-tuning method is introduced into the control scheme through the use of a Neuro-Fuzzy controller. First, a neural network represents a fuzzy controller. This network has three-layer and uses fuzzy sets (i.e. fuzzy membership functions) as its weights at the input and the output layers. The nodes of the hidden layer represent the fuzzy IF-THEN rules. The standard back-propagation procedure for multi-layer neural networks is adopted to train the fuzzy membership functions. The membership functions parameters change through the learning process such that the network interprets the desired input/output map of the controller as accurately as possible. Lastly, the parameters gained from the training procedure are fed back into the fuzzy system to produce the best control performance. In this research, a back-propagation algorithm in combination with a least squares method is utilized. The SNF controller is based on Sugeno or Takagi-Sugeno-Kang method [8].

3 Simulation results

'Matrix Reloaded' [9] video clip is used to implement the proposed SNF control scheme using computer simulation. In this paper, the first 100 GOPs of the clip is presented. MPEG uses intra-frame compression to remove redundancy within frames and inter-frame compression to take advantage of the redundancy contained over sequences of many pictures. This creates long Groups Of Pictures (GOPs) [10]. Based on Phase Alternate Line (PAL), in the Matlab-Simulink computer simulation it is assumed that there are 24 frames in one second and a GOP contains 12 frames; therefore in Fig. 2, 100 GOPs = 100 x 12 = 1200 frames. The contracted token-rate is set to 650 kb/s for the experiment.

In the computer simulation, N(e, v^2) is used as a Gaussian distribution, where, e is the mean value, and v is the standard deviation. A combined noise consists of a low-level rapid-changing noise and a high-level slow-changing noise is presented in Fig. 2 results. The low-level rapid-changing noise represents the overall effect of low-level interference in the Bluetooth channel. The high-level slow-changing noise represents the situation where an interfering device like microwave switches on and off from time to time. The sampling rates of the two combined noises are equal to a frame rate and a GOP rate, respectively. Their standard deviations are $50/3=\sqrt{278}$ and $200/3=\sqrt{4444}$, respectively. 50 and 200 are the differences between the minimum and the maximum token rate, and 3 is the maximum acceptable frame delay in the token bucket.

Fig. 2 presents the Matlab-Simulink computer simulation results for 'Matrix Reloaded'. The figure has 5 graphs, the fuzzified number of available tokens $\boldsymbol{Y(f)}$, the fuzzified queue length or capacity of the traffic-shaper $\boldsymbol{X(f)}$, the arrival bit rate to traffic-shaper $\boldsymbol{R_a}$, the departure bit rate from traffic-shaper $\boldsymbol{R_d}$, and the actual token (transmission) rate $\boldsymbol{r_{actual}}$. $\boldsymbol{Y(f)}$ and $\boldsymbol{X(f)}$ in Fig. 2 indicate as noise increases, less tokens would be available in the token bucket and more buffer capacity would be used from the traffic-shaper. Therefore, the $\boldsymbol{Y(f)}$ graph is presented to show the capacity of the token bucket during the video transmission, and also to indicate when the token bucket contract is likely to exceed. The graph for $\boldsymbol{X(f)}$ is presented to demonstrate the degree of saturation or starvation of the buffer. In Fig. 2, the burstiness of the departure bit rate $\boldsymbol{R_d}$ from the traffic shaper is reduced as compared with the arrival bit rate $\boldsymbol{R_a}$ to the traffic shaper, which results to a smoother data transmission over the Bluetooth channel. The introduction of the noise to the SNF scheme has a little effect over the departure bit rate $\boldsymbol{R_d}$. Fig. 2 demonstrates that the SNF scheme ensures that the actual token (transmission) rate $\boldsymbol{r_{actual}}$ is always below the contracted token rate of 650 kb/s.

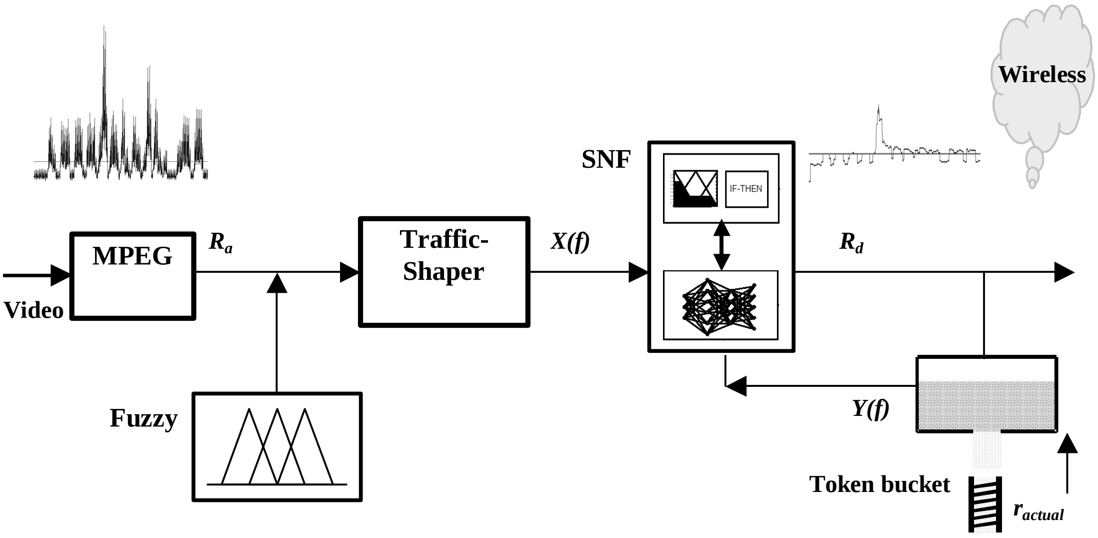

Fig. 1. The Self-tuning Neuro-Fuzzy scheme for video transmission over Bluetooth ACL.

4 Conclusion

The proposed Self-tuning Neuro-Fuzzy (SNF) controller is designed, implemented and compared with the open loop VBR encoding system for MPEG video over a Bluetooth ACL link. The computer simulation results demonstrate that the use of the SNF scheme reduces the standard deviation of output bit rate to the Bluetooth network, reduces the number of dropped data, and produces better and stable video image quality, as compared with the open loop VBR encoding system.

The SNF controller yields an improved image quality, because the SNF scheme acts as a master controller monitoring and adjusting the parameters of the membership functions of the fuzzy rules in the SNF to generate an appropriate departure rate $\boldsymbol{R_d}$ during the transmission period. The fuzzy rules in the SNF controller and the Fuzzy controller are pre-written in advance, predicting the network behavior. In a real-time video transmission over Bluetooth, the network might behave differently, as result of inherent volatility of the wireless environment. Therefore, the SNF system oversees and updates the membership functions to generate its own membership functions from the existing rules during the MPEG VBR video transmission, taking into account the new experiences encountered from the Bluetooth environment.

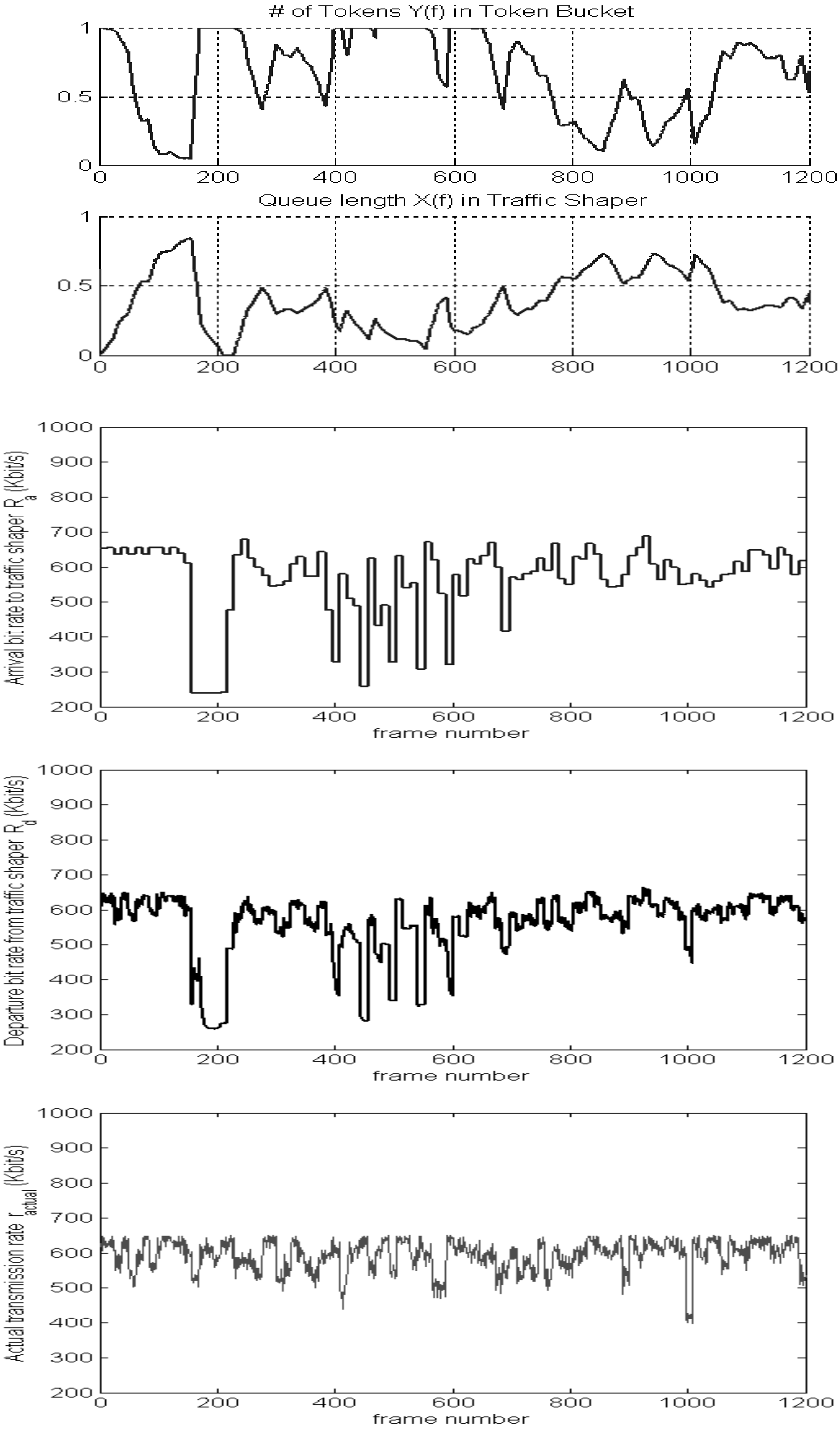

Fig. 2. ‘Matrix Reloaded’ – Output bit rate produced by the Self-tuning Neuro-Fuzzy controller

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