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Performance Analysis of Image Quality of MPEG Video with Neuro-Fuzzy method over BLUETOOTH

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Abstract— In a Bluetooth network, transmission rate can not be determined due to interferences by other wireless devices or general Bluetooth channel noises. MPEG Variable Bit Rate (VBR) video transmission is also not reliable and presents long delay and excessive data loss, due to variations in bit rate. It is therefore almost impossible to transmit MPEG VBR video over a Bluetooth channel, without data loss, excessive time delay or image quality degradation. Firstly, this paper presents a Traffic Shaping tool used to manage network traffic by shaping the traffic to a specified rate. Secondly, this paper presents an integrated Rule-Based-Fuzzy (RBF) approach and Neuro-Fuzzy (NF) scheme to Moving Picture Expert Group (MPEG) video transmission in Bluetooth. In general, a fuzzy scheme is more easily tuned by adjustment of the membership functions. By introducing two control inputs, a fuzzy scheme can trim its response. Finally, a packet-based algorithm functions like the early discard, and accept a newly arriving packet if the probability that all the cells of the packet are accepted is high.

Keywords— Bluetooth, Moving Picture Expert Group (MPEG), Variable Bit Rate(VBR), Rule-Based-Fuzzy(RBF), Neuro-Fuzzy(NF),network traffic.

I. INTRODUCTION

For the transmission over a network, digital video is compressed beforehand since it is data-hungry and requires a huge bandwidth for the extremely high bit rate[17]. From the service providers' point of view, the Moving Picture Expert Group (MPEG) Variable Bit Rate (VBR) encoding scheme is favoured to ensure a constant image quality. The level of image quality can be determined by the level of compression specified by the quantization parameter (QP) of the encoder. However, the burstiness of a VBR stream, i.e. the existence of sudden changes and big variance in its bit rate over time, will inevitably cause serious network congestion and data dropping and thus result in image quality degradation at the receiving end. To tackle such a problem, Constant Bit Rate (CBR) encoding scheme has been widely adopted in wired networks. CBR encoding scheme was first introduced to allow transmission of video signals over narrow-band integrated services digital network (ISDN). CBR uses a close loop to regulate the output bit rate from an MPEG encoder such that it conforms to a pre-set value. However, in a wireless network, due to mobility of the hosts and the interference in a radio-frequency (RF) environment, the actual transmission speed of a wireless link is unpredictable and highly variable and may become much lower than the contracted value. Subsequently, when transmitted over a wireless network a CBR encoded stream would face the same network congestion problem and suffer image degradation, just like VBR streams. This paper presents a control scheme developed specially for video transmission over wireless networks, which regulates the output bit rate from the MPEG encoder according to the current condition of the wireless channel. Fuzzy logic exploits the pervasive imprecision, uncertainty and partial truth of the real world using simple linguistic statements and thereby achieves tractability, robustness, and low solution cost. There have been comprehensive and successful studies into the application of fuzzy logic to many traffic control problems in wireless networks. In this research, the control procedure is carried out at the Host Controller Interface (HCI) of the wireless host at the sending end. The control scheme takes the current condition of the wireless channel into consideration. However, the idea of rate control according to the current link situation may be applied to any wireless networks.

This paper is organized as follows. First section describes the structure of the Bluetooth model for video transmission and the configuration of my simulation system. Second section outlines the structure and development of the fuzzy control scheme. Next section explains and compares the Matlab-Simulink computer simulation results for the real-time MPEG video clips. Last section will be the conclusion and the comparison of the results of the proposed scheme with the conventional VBR and CBR video schemes.

1.A EXISTING SYSTEM

In the existing system, the problem with the image quality degradation due to several deficiencies and old algorithm is solved and developed. In that existing system there is no application of Neuro-Fuzzy algorithm or the Rule Based system. The encoded MPEG video is directly sent to the air through a buffer.

The below figure illustrates the existing system.

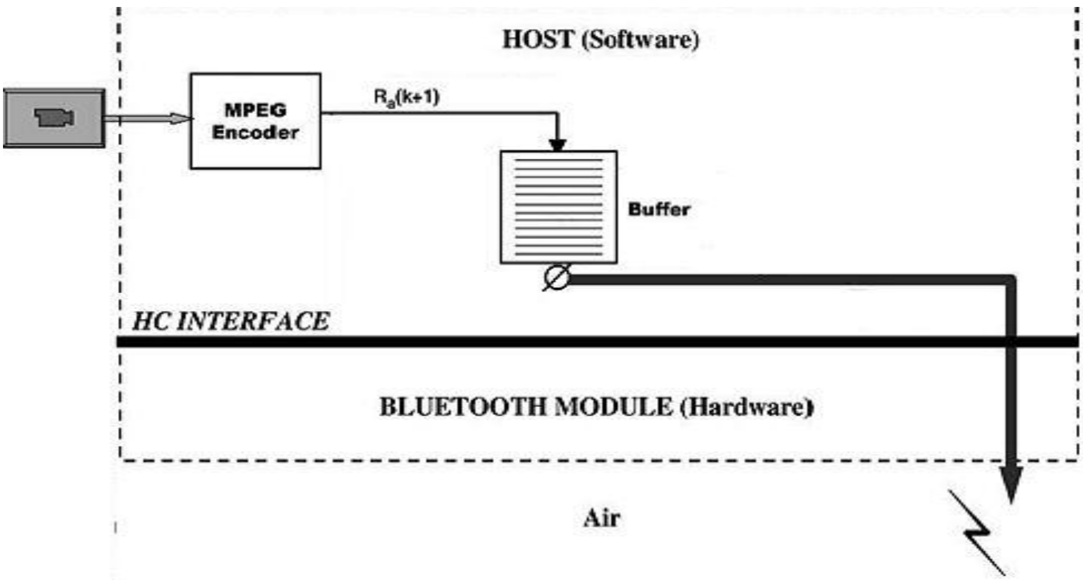

Fig 1: Existing Systems

1.B Frame size of the MPEG video:

The frame size is not set properly before it is delivered over BLUETOOTH network. The bigger frame size causes the degradation of the image quality when it is received on the other end or the intended receiver. This causes the variation in the image of the MPEG video.

1.C UNPREDICTABLE TRANSMISSION RATE:

In a Bluetooth network, transmission rate is unpredictable due to interferences by other wireless devices or general Bluetooth channel noises. MPEG Variable Bit Rate (VBR) video transmission is also unreliable and presents long delay and excessive data loss, due to variations in bit rate. It is therefore almost impossible to transmit MPEG VBR video over a Bluetooth channel, without data loss, excessive time delay or image quality degradation.

II. DESCRIPTION OF THE PROPOSED MODULES

This paper will be divided into several phases mentioned below:

1. MPEG Encoder
2. Traffic Shaping Buffer
3. Rule-based-fuzzy implementation.
4. Neuro-Fuzzy implementation
5. Leaky Bucket(GCRA)
6. DATA FLOW DIAGRAM

Descriptions of the above modules are as follows

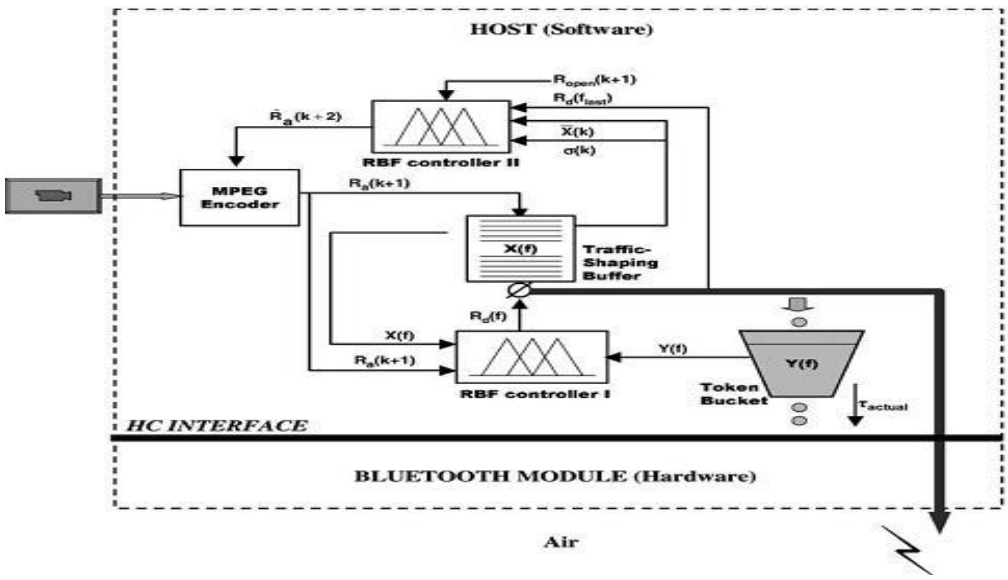

Figure 2 : Architecture of the Proposed Model

2.A MPEG Encoder:

Basic Function:

- AVI/MPEG video will be given to MPEG Encoder to encode the information before it is sent to Traffic-Shaping Buffer.
- The level of image quality can be determined by the level of compression specified by the quantization parameter (QP) of the encoder.

2.A.1 General description:

The MPEG-4 encoder is a hardware module optimized for FPGA technologies, making use of a limited number of logic resources and being able to encode a 4CIF (704x576) sequence in real time. It is fully compliant with the Video part of ISO/IEC 14496-2. All visual tools of the Simple Profile are implemented, including full support of I-VOP (intra-coded frames, without motion estimation) and P-VOP (predictive-coded frame, with motion estimation on previously encoded frame).

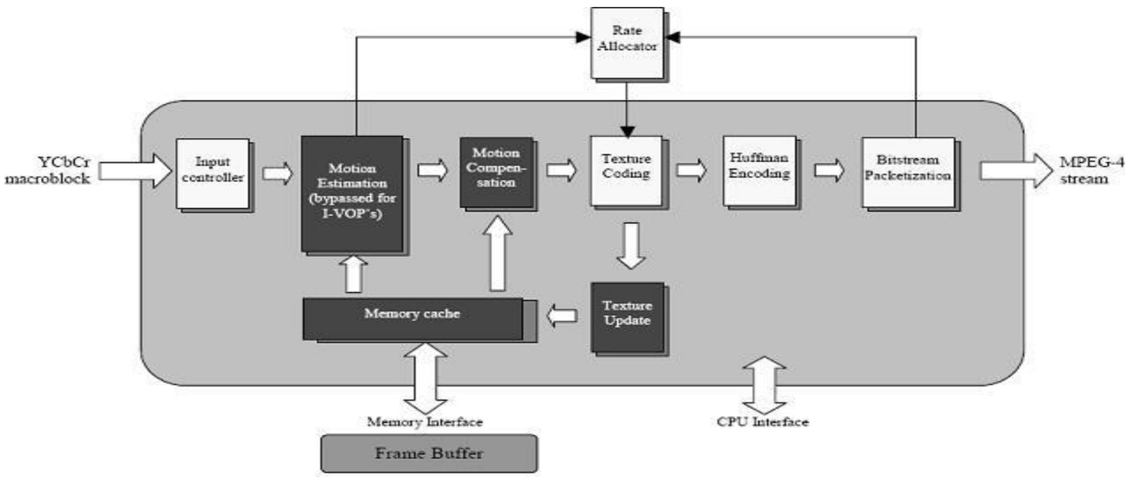

Fig 3: Block Diagram of the BA131MPEG4E IP

2.A.2 Applications:

- Video broadcast
- Security and Surveillance
- Multimedia streaming over TCP/IP
- Mobile communications

2.A.3 Technical description:

Figure 2 illustrates a simplified block diagram of the BA131MPEG4E IP showing the internal modules and its interfaces. The video data is organized in macro blocks under YUV format (4:2:0 resolutions). One macro block is made of 4 luminance blocks (8x8), 1 Cb block (8x8) and 1 Cr block (8x8). The video data is sent to the core through its video interface in macro block raster scan order. It generates the compressed stream at its Compressed Data Interface. The stream contains fully compliant headers and is regulated to a given bit rate if the CBR option is enabled (together with external microprocessor running the rate allocation algorithm). The encoder has a generic interface to a memory controller, allowing the connection to any custom memory controller. Thanks to the burst nature of data transfers at this interface, the core can be used with simple SRAM but also SDRAM or DDR SDRAM. The core can be delivered with a standard SRAM controller; a suitable SDRAM controller is separately available. The core has been optimized in order to minimize the amount and bandwidth of off-chip memory. A single frame needs to be stored and accesses are reduced to 1 read and 1 write per input sample. The encoder has a simple generic interface to an external CPU in order to configure the various parameters of the core and to monitor the status of the encoding process. The following sections describe the modules constituting the BA131MPEG4E core as depicted under Figure 2.

2.A.4 Motion estimation:

The first module of the core is the motion estimation engine. This module is bypassed for Intra-coded pictures (I-VOP), which are not coded with reference to any other picture. Technical specifications are subject to change without prior notice. The motion estimation engine uses an advanced directional search algorithm able to precisely and rapidly match the current macro block (16x16 pixels) with its equivalent in the reference frame. The core uses the frame stored in external memory as a reference. The processing generates one motion vector per macro block, giving the direction and amplitude of the detected motion. The matching precision is half a pixel. The motion estimation engine features advanced capabilities in order to shorten the search time as much as possible. This module also delivers statistics used by the rate allocation algorithm. The module also detects when a macro block cannot be registered correctly to the reference frame and should better be encoded as an Intra macro block.

2.A.5 Motion compensation:

This module computes the estimation error induced by the use of the vector generated by the motion estimation engine. This module is bypassed for Intra-coded pictures (I-VOP). It makes the difference between the current macro block (in luminance and chrominance planes) and the predicted macro block from the reference frame, using the estimated motion vector. The result is known as the prediction error and must be encoded by the texture coding.

2.A.6 Texture coding:

This module encodes error frames when using P-VOPs (resulting from motion compensation) or completes frames when using I-VOPs. This module has advanced low-power features where part of the processing is switched off when it is detected to be useless. An approximation of its result is then used instead. The texture coding is made of Discrete Cosine Transform (DCT), AC/DC prediction, quantization and zigzag encoding and works on block level (8x8):

- The DCT de-correlates the frequency contents of the 8x8 blocks and delivers a matrix of 64 frequency coefficients, representing the frequency contents of the original block of data.
- This is then quantized using a scalar quantizer. The quantization factor is programmable by the user, allowing him to set the quality level.
- The AC/DC predictor is used for I-VOPs and performs a prediction of the first line or the first column of the quantized matrix, based on the transformed blocks situated on the left and on top of the current block. The prediction source (top or left) is determined by a gradient analysis of DC coefficients of the transformed blocks situated on top, top-left and left. This prediction results in a higher compression efficiency.
- The quantized matrix is then processed by the zigzag encoder, which reads this 8x8 matrix in a predefined scan order; this results in a chain of coefficients where most of these are zeros. This is then further encoded thanks to a run encoder in order to reduce the size of the representation.

2.A.7 Entropy encoder:

The entropy encoder finalizes the data compression by applying a Huffman encoding to both the motion vectors and the compressed pixels. This module uses pre-defined look-up tables.

2.A.8 Bitstream packetization:

This module generates compliant MPEG-4 VOL and VOP headers (short headers and data partitioning are not supported but the core can be customized to add these features). The encoder includes an output buffer allowing the user to generate a stream at constant bit rate (CBR mode) by coupling the core to a small microprocessor running a rate allocation algorithm (Nios or Microblaze for instance). The rate allocation algorithm can be purchased optionally.

2.A.9 Texture update:

This feedback loop is performing the inverse operations of the texture coding: unzigzag, inverse quantization and Inverse Discrete Cosine Transform (IDCT). This allows the encoder to take into account quantization errors occurring at the decoder side when the picture is decoded. The encoder then uses the result of this texture update module to update the contents of the frame store (when needed). This new contents is then ready to be used as a reference frame for encoding the next frame. Technical specifications are subject to change without prior notice.

2.A.10 Rate allocator:

This optional module is dedicated to regulate the output of the encoding IP core to the bit rate specified by the user. This module makes use of a patented rate allocation algorithm, exploiting statistical information available at the motion estimation to improve its efficiency and provide a more stable stream bit rate and quality. This module is implemented as software code able to run on a simple processor (Nios or Microblaze for instance). The rate allocator can also be customized to be mapped as a 100% hardware block.

2.A.11 Video Compression:

The aim of video compression is to remove redundant information from a digitized video sequence. It is critical to choose an appropriate compression method for use in video streaming over Bluetooth, as it provides time-varying wireless link with limited bandwidth up to 732Kbps. This section briefly describes video compression techniques including MPEG-4 and H.263 that are used by current researches of this area.

2.A.12 MPEG-4 :

A large portion of works [1, 3, 4, and 8] reviewed in previous sections employ MPEG-4 as video codec for streaming over Bluetooth. MPEG-4 is one of the newest video compression techniques and allows much lower compression ratios than the previous MPEG-2. MPEG-4 is ideally suited to low bandwidth applications, exactly matching the requirements for video over a wireless Bluetooth network. MPEG-4 uses motion vectors between frames to encode temporal redundancy and the discrete cosine transform (DCT) to encode spatial redundancy. MPEG-4 provides three modes for encoding an input , these are namely:

1. Intra-frame (I-frame) is encoded independently of any other frame and can be constructed without reference to any other frames.
2. Predicted-frame (P-frame) is predicted (using motion compensation) based on another previously decoded I-frame.

3. Bidirectional Interpolated-frame (B-frame) is predicted based on past as well as future frames.

For frames other than I frames, the amount of information to be coded reduces to differences between frames. This differential coding means that I frames are more important since all future frames till the next I frame are coded based on it. Therefore, extensive research on exploiting the information on the type of video frames has been proposed. Among these researches, *upper layer retransmission* mentioned in **3.1.3** is a kind of selective retransmission based on semantic importance of MPEG -4 frames in the context of streaming over Bluetooth links.

2.A.13 H.263

Several works reviewed in previous section employ H.263 as video codec for streaming over Bluetooth.
H.263 is a video compression algorithm and protocol which is standardized by ITU. It was designed for low bit-rate communication. The video source coding algorithm of H.263 is based on Recommendation
H.261 and is a hybrid of inter-picture prediction to utilize temporal redundancy and transform coding of the remaining signal to reduce spatial redundancy, however with some changes to improve performance and error recovery. H.263 lets users scale bandwidth usage and can achieve full motion video (30 frames per second) at speeds as low as 128Kbps. H.263 was also developed to low-quality stream video at bandwidths as low as 20 to 64Kbps.
Compared to MPEG-4, H.263 does not support some of the features such as compression efficiency and channel error robustness. However, it is widely accepted that it performs well for the target application at bi-rate between 20 and 64 Kbps. Therefore it is widely used in wireless networks with limited bandwidth.
It is investigated that a fuzzy logic-based video rate control technique which aims to regulate compressed video to a constant transmission rate, without incurring objectionable quality degradation. Conventional fuzzy rule-based control (FRC) does not adequately control the output video quality. Video information is therefore added into the FRC design by incorporating feed-forward scaling factors, derived from scene
change features. The performance of this coder has been compared with other approaches measuring buffer occupancy, the number of coded bits per frame and peak signal-to-noise ratio.

2.B Traffic Shaping Buffer:

This is a temporary storage to smooth the video output traffic and partially eliminate the burstiness of the video stream entering Bluetooth wireless. Traffic shaping allows you to control outgoing traffic on an interface to match the traffic speed of the remote target interface and to ensure that the traffic conforms to specific policies. Traffic that adheres to a particular profile can be shaped to meet downstream requirements, thereby eliminating bottlenecks in topologies caused by data-rate mismatches. Traffic management is an important function in Bluetooth networks. The leaky bucket algorithm is a general algorithm that can be effectively used to police real time traffic. Frame Relay and network use a form of the leaky bucket algorithm for traffic management. Frame Relay networks use a continuous state version of the leaky bucket algorithm called the Generic Cell Rate Algorithm (GCRA) to police traffic at the entrance to the Frame Relay network. The network traffic consists of fixed size cells/packets.

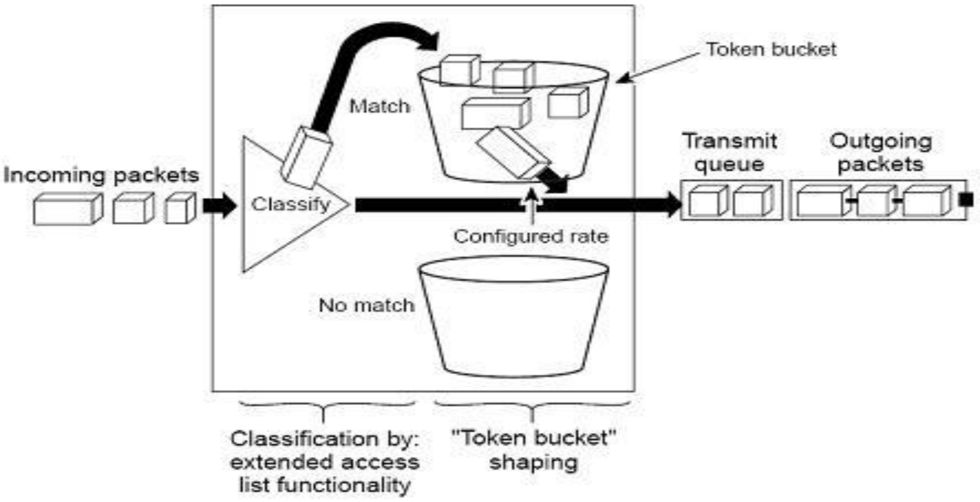

Fig 4: A General example of Traffic Shaping Buffer

2.B.1 Benefits of Shaping Traffic on a Network:

The benefits of shaping traffic on the network include the following:
It allows you to control the traffic going out an interface, matching the traffic flow to the speed of the interface.
It ensures that traffic conforms to the policies contracted for it.
Traffic shaping helps to ensure that a packet adheres to a stipulated contract and determines the appropriate quality of service to apply to the packet.
It avoids bottlenecks and data-rate mismatches. For instance, central-to-remote site data speed mismatches.
Traffic shaping prevents packet loss.

2.B.2 Using traffic shaping buffer in various scenarios:

Control access to bandwidth when, for example, policy dictates that the rate of a given interface should not on the average exceed a certain rate even though the access rate exceeds the speed. Configure traffic shaping on an interface if you have a network with differing access rates. Suppose that one end of the link in a Frame Relay network runs at 256 kbps and the other end of the link runs at 128 kbps. Sending packets at 256 kbps could cause failure of the applications using the link.

2.C Neuro-Fuzzy implementation

This is an integrated controller which monitors the output rate or departure rate of the traffic-shaping buffer frame by frame to co-ordinate the video traffic entering Bluetooth. The inputs to the NF controller are the queue length in the traffic-shaping buffer $X(f)$ and the available memory space in the token-bucket $Y(f)$. The output from the NF controller is departure rate $R_d(f)$, will be measured in kilobits per second.

2.D Rule-based-fuzzy implementation

This controller regulates the average arrival rate to the traffic-shaper to prevent either overflow or starvation of the buffer on a Group Of Picture (GOP) by GOP basis.

The inputs to the RBF controller are the mean X(f) and standard deviation Σ(X) of queue length in the traffic-shaping buffer. The output from the RBF controller is the desired arrival rate. Automatic design of fuzzy rule-based classification systems based on labeled data is considered. It is recognized that both classification performance and interpretability are of major importance and effort is made to keep the resulting rule bases small and comprehensible. An iterative approach for developing fuzzy classifiers is proposed. The initial model is derived from the data and subsequently, feature selection and rule base simplification are applied to reduce the model, and a GA is used for model tuning. An application to the Wine data classification problem is shown.

Rule-based expert systems are often applied to classification problems in fault detection, biology, medicine etc. Fuzzy logic improves classification and decision support systems by allowing the use of overlapping class definitions and improves the interpretability of the results by providing more insight into the classifier structure and decision making process. The automatic determination of fuzzy classification rules from data has been approached by several different techniques: neuro-fuzzy methods, genetic-algorithm based rule selection and fuzzy clustering in combination with GA-optimization.

2.D.1 The Model Structure

Fuzzy classification rules are applied that each describe one of the N_c classes in the data set. The rule antecedent is a fuzzy description in the n-dimensional feature space and the rule consequent is a crisp (non-fuzzy) class label from the set f={1; 2; : : : ;N_c}:

$$R_i: \text{ If } x_1 \text{ is } A_{i1} \text{ and } \ldots x_n \text{ is } A_{in} \text{ then } g_i = p_i,\ i = 1, \ldots, M$$ Eq….. (4.1.1.1)

Here n denotes the number of features,x = [x_1; x_2; : : : ; x_n].

T is the input vector, gi is the output of the i^{th} rule and

A_{i1}; : : : ;A_{in} are the antecedent fuzzy sets. The and connective is modeled by the product operator, allowing for interaction between the propositions in the antecedent. The degree of activation of the ith rule is calculated as:

$$\beta_i(x) = \prod_{j=1}^{n} A_{ij}(x_j), \quad i = 1, 2, \ldots, M$$

Eq….. (4.1.1.1)

The output of the classifier is determined by the rule that has the highest degree of activation:

$$y = g_{i^*}\ ,\ i^* = \underset{1<i<M}{\arg\max}\ \beta_i$$

Eq.... (4.1.1.3)

In the following we assume that the number of rules corresponds to the number of classes, i.e., M = N_c. The certainty degree of the decision is given by the normalized degree of _ring of the rule:

$$CF = \beta_{i^*} / \sum_{i}^{M} \beta_i$$

Eq.. (4.1.1.4)

2.D.2 RBF Network Architecture:

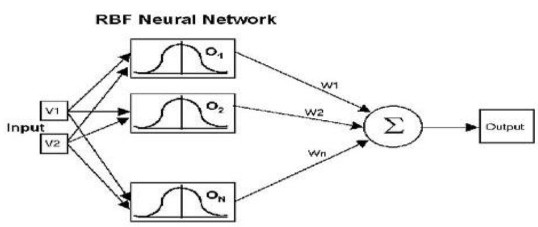

Fig 5: RBF networks Layers

2.D.3 RBF networks have three layers:

Input layer – There is one neuron in the input layer for each predictor variable. In the case of categorical variables, N-1 neurons are used where N is the number of categories. The input neurons (or processing before the input layer) standardize the range of the values by subtracting the median and dividing by the interquartile range. The input neurons then feed the values to each of the neurons in the hidden layer. Hidden layer – This layer has a variable number of neurons (the optimal number is determined by the training process). Each neuron consists of a radial basis function centered on a point with as many dimensions as there are predictor variables. The spread (radius) of the RBF function may be different for each dimension. The centers and spreads are determined by the training process. When presented with the x vector of input values from the input layer, a hidden neuron computes the Euclidean distance of the test case from the neuron's center point and then applies the RBF kernel function to this distance using the spread values. The resulting value is passed to the the summation layer.

Summation layer – The value coming out of a neuron in the hidden layer is multiplied by a weight associated with the neuron (W1, W2, ...,Wn in this figure) and passed to the summation which adds up the weighted values and presents this sum as the output of the network. Not shown in this figure is a bias value of 1.0 that is multiplied by a weight W0 and fed into the summation layer. For classification problems, there is one output (and a separate set of weights and summation unit) for each target category. The value output for a category is the probability that the case being evaluated has that category.

2.E Leaky Bucket (GCRA):

Traffic-rate policing will be carried out by means of the Generic Cell Rate Algorithm (GCRA) – a rule by which video streams can be judged to be complying with the terms of the traffic contract, GCRA is commonly known as 'leaky bucket' or 'token-bucket'.

The token-bucket will be located prior to the HCI and measures the departure rate against the contracted mean rate. The actual token-rate r_{actual} will be varied according to the level of interferences in the Bluetooth channel and its environment. The contracted token-rate is the maximum bandwidth for a Bluetooth ACL link, which will be set around 650 kb/s with 32 kb/s for the sound and 618 kb/s for the video images. The leaky bucket is a "traffic shaper": It changes the characteristics of a packet stream. Traffic shaping makes the network more manageable and predictable. Usually the network tells the leaky bucket the rate at which it may send packets when a connection is established.

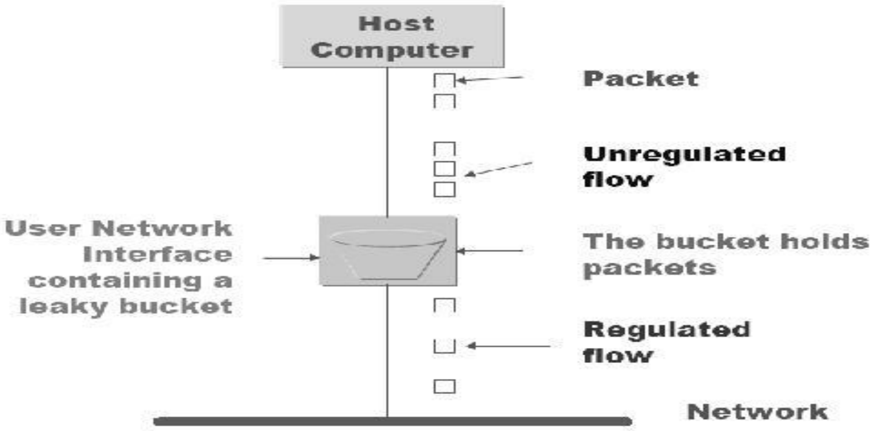

Fig 6: AN EXAMPLE OF GCRA

2.F DATA FLOW DIAGRAM

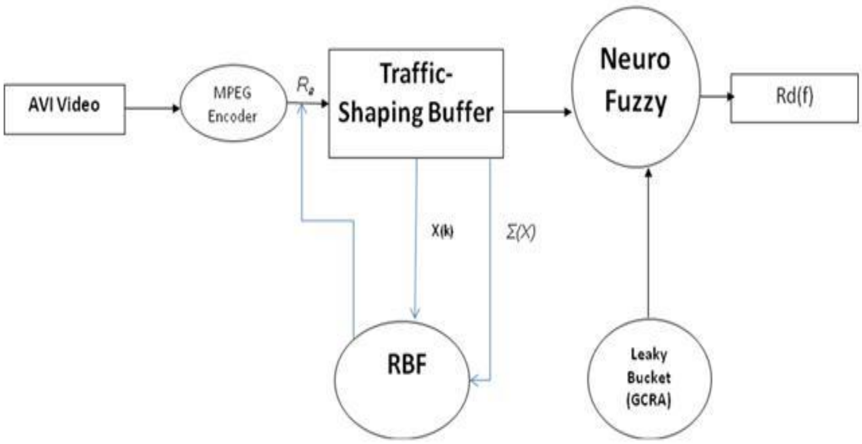

Fig 7: Data Flow Systems

III. RESULTS OF SIMULATION

X(f): Output from the Traffic Shaping Buffer:

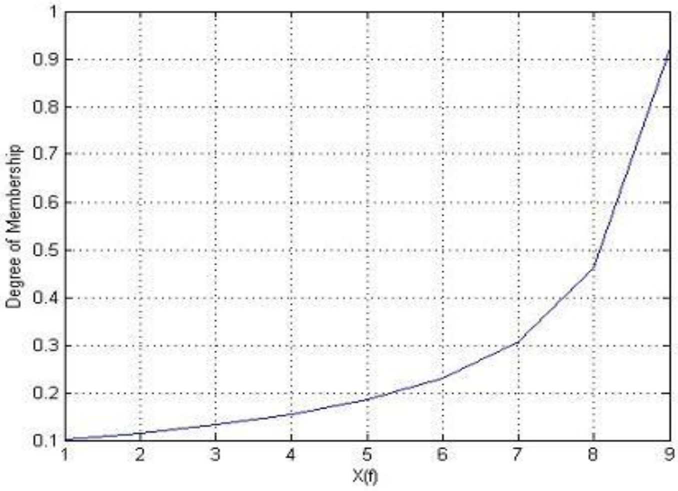

Fig 8: X(f): Output from the Traffic Shaping Buffer

Y(f): Token Space Available in Token Bucket:

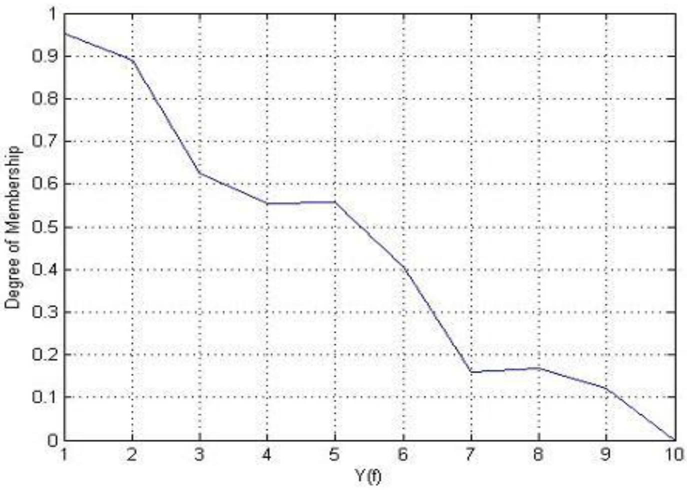

Fig 9: **Y(f): Token Space Available in Token Bucket:**

id(f): Final Departure of Packets to Bluetooth Link:

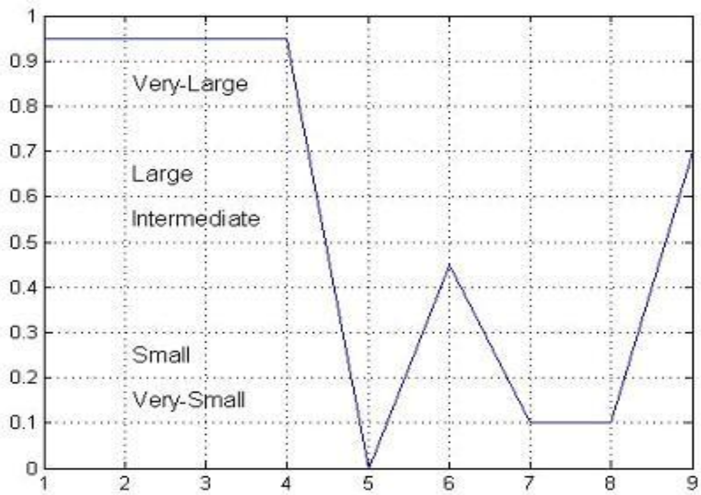

Fig 10: id(f): Final Departure of Packets to Bluetooth Link

id(f): Sugeno Model:

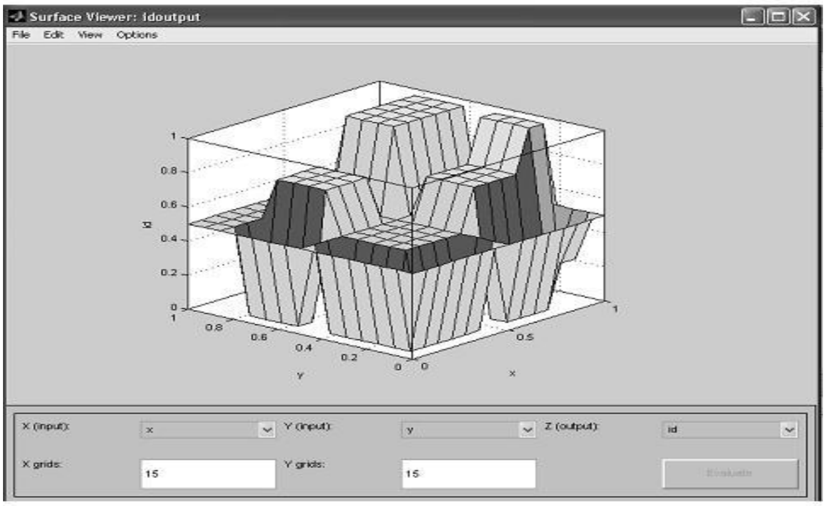

Fig11: id(f): Sugeno Model

RTO (Retransmission Limit Mamdani Model):

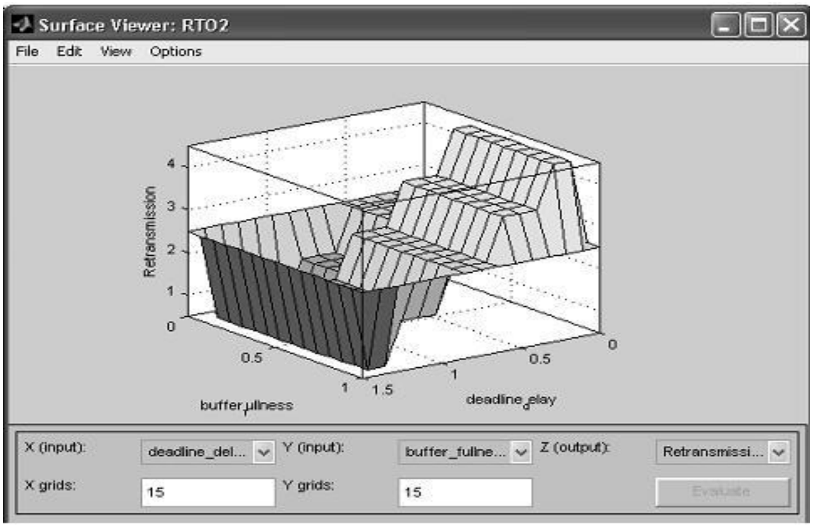

Fig 12: RTO (Retransmission Limit Mamdani Model):

IV. CONCULATION

This paper presents the proposal on a fuzzy approach to video transmission over Bluetooth wireless. The VoIP technology will be used to allow MPEG video to be transmitted using the higher bandwidth supported by the Bluetooth ACL links. To simulate the interference in the Bluetooth channel, a Gaussian noise will be added to the contracted token rate. Furthermore, in order to address the network congestion problem caused by the burstiness of video stream bit rate, a fuzzy control scheme will be developed. The control scheme introduces a traffic-shaping buffer and two rule-based fuzzy controllers. The two rule-based fuzzy controllers will adjust the input bit rate to and the output bit rate from the traffic-shaper.

In comparison with the open loop VBR system, the proposed control system will significantly reduce both the variance of output bit rate to the network and the number of dropped data, which ultimately will result to a guarantee in data source stability while maintaining image quality at the receiving end. In comparison with a conventional CBR system, the proposed system takes the current network conditions into consideration; it will reduce the amount of dropped data in presence of very high-level (combined noise) interference in the Bluetooth channel.

This work is concerned with reduction of oversubscribed MPEG VBR video transmission over a Bluetooth ACL link. A novel integrated Neuro-Fuzzy (NF) control scheme is utilized to reduce the burstiness of the traffic-shaping buffer output rate to enable the VBR encoded video to enter the Bluetooth network reducing time delay, data loss and image quality degradation. The proposed NF scheme considerably reduces the standard deviation of the output bit rate to the Bluetooth channel and the number of dropped-data, which ultimately result to data transmission stability, while maintaining image quality at the receiving end. The NF control scheme also improves and maintains the quality of service with noise interferences over the Bluetooth channel. In conclusion, as the integrated NF and RBF schemes are both based on simple algorithms, the overall control system only requires an acceptable processing power, which could be used for real-time implementations in delay-sensitive MPEG VBR video services in mobile devices. Rule-based expert systems have been applied in a vast number of application areas. An important advantage of the fuzzy expert system is that the knowledge is expressed as easy-to-understand linguistic rules. If we have data, the fuzzy expert system can be taught using neural network[11] learning, EC, or other adaptation techniques. It is to be expected that the number of applications will grow considerably in the future now that success is clearly proven for these methods.

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