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Efficient Bluetooth Video Transmission with Resource Manager

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Abstract

A scheme of wireless real video transmission with optimized Quality-of-service is proposed in this paper. It combines H.264 video compression technology with Bluetooth technology to reduce demand of bandwidth and power consumption. Resource manager (RM) is used to smooth video output traffic and to partially eliminate peak of video stream transmitted in Bluetooth channel. The RM monitors status of video transmitters, manipulates and coordinates the being encoded video, and adopts traffic credits to support real-time video services. Measured results show that a maximal speed of transmission can be achieved with a best suitable ACL packets type, rather than the maximum payload packet, according to SNR to achieve. The system can support real-time video transmission with good quality. And more, it can be realized easily in mobile application for its good transportability and robustness.

Keywords: *image transmission, real-time imaging, image quality*

1. Introduction

Video communication over wireless networks is an increasing technology in a wide range of important applications [1, 2]. In order to reduce the image data traffic, video compression is general employed in a video codec. There are some video compression standards such as H.263, H.264 and MPEG4. Among these standards, H.264 [3] has more advanced compression methods than the MPEG-4 compression, having significant improvements in coding efficiency, error robustness and network friendliness, meeting the growing demands for video compression application in embedded system [4].

In order to realize wireless communication over short distances in embedded system, Bluetooth and WiFi are two main technologies to choice recently. Bluetooth is reported to be more power-efficient [5-7] than WiFi. Video transmission over Bluetooth [8-10] is still a valuable research topic. Recently, the Bluetooth v4.2 Specification [11] is released on December 2014. But it aims at very low power applications running off a coin cell, which is unsuited for wireless video transmission. Bluetooth v3.0+HS (High-Speed) Specification is released on 21 April 2009. It supports theoretical data transfer speeds of up to 24 Mbit/s, of which the high data rate traffic is carried over a colocated 802.11 link and consumes more energy.

Considering of limited battery lifetime, embedded device adopting Bluetooth technology does not support High-Speed at present, which adopts EDR technique to achieve a high spend to transmit. Therefore, a scheme of Video transmission adopting real-time H.264 video sequences transmission over Bluetooth 2.1+EDR in embedded system is proposed in the paper. In order to solve the problem that H.264 variable bit rate (VBR) in video transmission is unreliable and Bluetooth channel is instable, it adopts resource manager (RM) to control video transmission, which analyzes the condition of

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Bluetooth, and uses a method of traffic credits and a buffer to smooth the video output traffic and to partially eliminate the peaking of the video stream transmitted in Bluetooth channel. In order to achieve a maximal speed of transmit, a best appropriate ACL packets type, rather than the maximum payload packet, is chosen in the system according to SNR. And more, numbers of key video parameters for good video quality in the system are advised in the paper.

2. Design of Real Time Bluetooth Video Transmission System

To meet the requirements of mobile multimedia application, a complete solution scheme of multimedia-enable embedded system is proposed. As is shown in Figure 1, a client-server system is adopted in the basic architecture. The video sender transmits video stream over Bluetooth links to reach the video receiver. The video sender acts as server and the video receiver acts as client. The Video sender includes a H.264 Encoder, a Bluetooth module and an ARM11 processor.

In order to maintain a stable real-time video stream output, it is important to provide a support of guaranteed Quality of Service (QoS) [12]. The specified and implemented QoS mechanisms of Bluetooth includes FEC coding, retransmissions, fragmentation and packet scheduling, but they are not sufficient enough for embedded real-time video transmission system, especially under the condition that there are too much video streams to be transmitted.

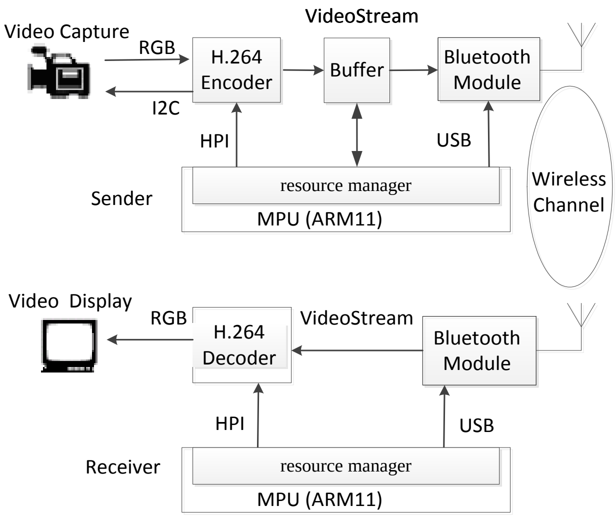

Figure 1. H.264 Video Transmission System over Bluetooth

A RM is added above the HCI layer to control stream data rate accessing to network in our system, as is shown in Figure 2. The RM monitors the actual state of the network and video stream. If the state of the network is bad, such as heavy traffic load, large bit-error rate, the RM informs the video layer to adjust the H.264 codec settings (such as frame rate, bit rate *etc.*). To further improve the video quality, a buffer is introduced in RM to manipulate and coordinate the encoding video before entering the Bluetooth channel at sender. The role of the buffer is to smooth the video output traffic and to partially eliminate the peaking of the video stream entering the Bluetooth network. When the bitrate streaming is greater than the Bluetooth transfer rate, data would be held in reserve in the buffer. In the case that the memory space in this buffer is almost full, the RM also informs the video layer to avoid dropping more video-stream or frames.

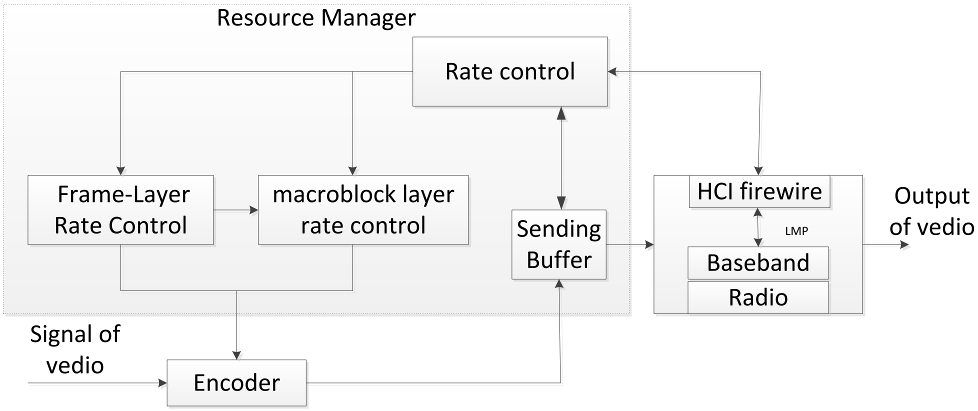

Figure 2. Schematic of Resource Manager

The video sender and receiver know their working status with the RM. During the linking process between client and server, several virtual traffic channels are built up to transfer data by the RM. Corresponding to these channels, there are some input or output ports labeled as traffic credits at the receiver and sender end, respectively. If the sender sends one packet, the traffic credit will minus one, which means that one channel is used. After the receiver gets one packet, it will inform the sender that one channel is released and can be reused again by sending a command. When the sender receives this command, the traffic credit will add one. Number of the traffic credits will decrease when data is transmitted. If the available credits are insufficient, the traffic is non-conformant, which may be that the receiver spends much time on dealing with one packet/frame or the Bluetooth link which is not in good condition. In these cases, video server need to adjust transmit speed at the sender to keep good QoS.

3. Analysis and Test of the Proposed System

The requirements of video transmission adopting H.264 technology depend on the desired video quality. The video server can deliver streams with different resolutions, frame rates and compression bit rate. The range of these parameters is wide. Therefore, how to choose appropriate parameters is considerable. But the use of Bluetooth restricts the range of these parameters because of limited bandwidth of Bluetooth. The following tests will reveal how to choose the best parameters in our embedded system.

The measurements are performed in a furnished 15 m by 30 m meeting room, with chairs and desks in the middle of the room, in our office building. We use two Bluetooth devices with the spacing of 10 meters.

3.1. Transfer Bit Rate of Bluetooth

The tests are repeated for different targeting compression bit ranging in 256kbps increments from 512Kbps to 2048Kbps. The size of encoded pictures is 352 pixels by 288 pixels, 496 pixels by 384 pixels and 640 pixels by 480 pixels, respectively. And the average encoding speed of them is about 30fps. When video is rebuilt at the receiving end, the actual transfer bit rates can be obtained by measuring the total numbers of received data bits within a predetermined time span.

As shown in Figure 3, the actual transfer bit rates are almost equal to the targeting compression bit rate for these three resolutions when the targeting compression bit rate is lower than 1.6Mbps. However, if the targeting compression bit rate is higher than 1.6Mbps, the received bit rates will not follow the increase of the targeting ones anymore.

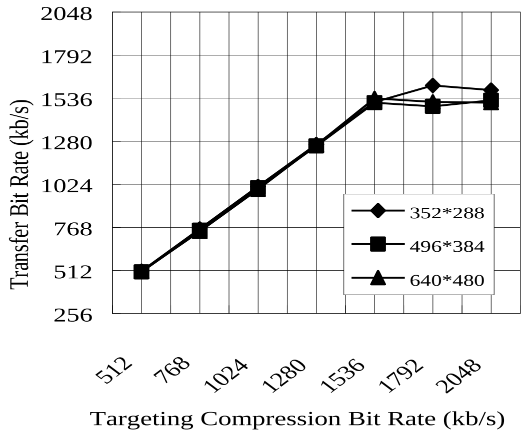

Figure 3. Bluetooth Transfer Rate Depends on Video Targeting Compression Rate for Difference Resolutions

In the enhanced data rate (EDR) standard of Bluetooth 2.1, the maximum theoretical throughput is 2.178Mbps. However, the actual transfer bit rate is still subject to ARQ in the presence of errors [13]. Suppose $\overline{N}$ is the average number of times that a particular ACL packet must be transmitted.

$$\overline{N} = \frac{1}{1 - \overline{P}_r(\overline{\gamma})} \tag{1}$$

Where $\overline{\gamma}$ is the average SNR (Signal-to-Noise Ratio), $\overline{P}_r(\overline{\gamma})$ is the corresponding average channel error probability [14]. For any particular type of packet, the data rate R is a function of $\overline{N}$.

$$R = \frac{K}{D\overline{N}625 \times 10^{-6}} = \frac{K(1 - \overline{P}_r(\overline{\gamma}))}{0.000625D} \tag{2}$$

Where D is the number of occupied slots per transmission including the return packet, and one slot time is 625usec. K is the number of data bits in the packet, as is shown in Table 1.

The average throughput can be gotten by taking the expected value of R with respect to $\overline{N}$.

$$R_{avg} = E_{\overline{N}}\{R\} \tag{3}$$

Figure 4 shows the throughput performance against SNR. At high SNR, the throughput converges to the maximum permissible value for each packet type (for example, 340kbps for 2-DH1, 1.4Mbps for 2-DH5, 1.7Mbps for 3-DH3). But different packets achieve maximum throughput at low SNR. For SNR< 10db, the 2-DH1 packets provide the best throughput. For 15db < SNR < 20db, the 2-DH5 packets are the proper choice. This implies that the packet type should be adaptively selected to match the channel SNR in order to achieve maximal.

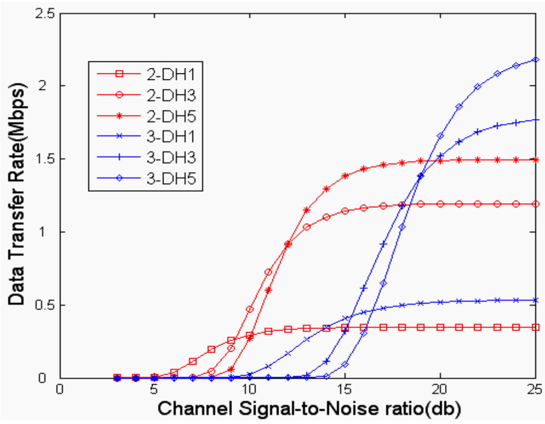

Figure 4. Average Transfer Rate of Bluetooth ACL Packets vs Channel SNR

Table 1. ACL Packets for Enhanced Data Rate

Type	FEC	CRC	Symmetric Max Rate (kbps)	Asymmetric Max Rate (kbps)	
				Forward	Reverse
2-DH1	no	yes	345.6	345.6	345.6
2-DH3	no	yes	782.9	1174.4	172.8
2-DH5	no	yes	869.7	1448.5	115.2
3-DH1	no	yes	531.2	531.2	531.2
3-DH3	no	yes	1177.6	1766.4	235.6
3-DH5	no	yes	1306.9	2178.1	177.1

Therefore, Bluetooth will select the best appropriate ACL packets type according to SNR, rather than the maximum payload packet 3-DH5. The average data transfer rate cannot achieve the maximum rate. This test suggests that the Bluetooth link is saturated around 1.6Mbps in our system. And this transfer bit rate is far higher than ref [15] which transfer bit rate is only 700kbps. Thus it is possible to transmit high quality video in our system.

3.2. Number of Lost Data

In this test, the average lost packets in L2CAP layer and dropped video frames can be calculated by the difference between the sender and the receiver in three minutes.

Figure 5 shows the relation between numbers of lost packets and targeting bit rate. At the targeting bit rate of 1536kbps, the numbers of lost packets among 352 pixels by 288 pixels, 496 pixels by 384 pixels and 640 pixels by 480 pixels are 4, 27, and 93, respectively. At the targeting bit rate of 512kbps, the numbers of lost packets among 352 pixels by 288 pixels, 496 pixels by 384 pixels and 640 pixels by 480 pixels are 1, 3, and 24, respectively. Because the size of 352 pixels by 288 pixels is less than that of 496 pixels by 384 pixels or 640 pixels by 480 pixels, the numbers of lost packets is less than that of the latters.

Figure 6 shows the relation between numbers of dropped frames and targeting bit rate. At the targeting bit rate of 1536kbps, the numbers of dropped frames among 352 pixels by 288 pixels, 496 pixels by 384 pixels and 640 pixels by 480 pixels are 5, 39, and 113, respectively. At the targeting bit rate of 512kbps, the numbers of dropped frames among 352 pixels by 288 pixels, 496 pixels by 384 pixels and 640 pixels by 480 pixels are 2, 5, and 40, respectively. Because the size of 352 pixels by 288 pixels is less than that of 496 pixels by 384 pixels or 640 pixels by 480 pixels, the numbers of dropped frames is less than that of the latters.

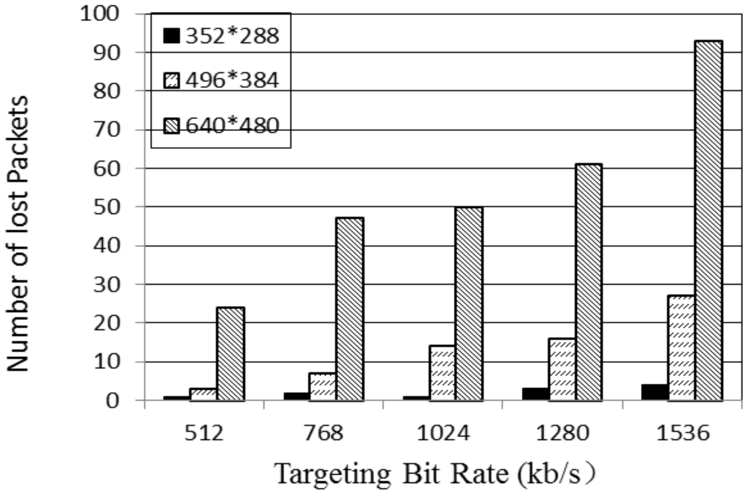

Figure 5. Average Numbers of Lost Packets Depend on Difference Resolutions in Three Minutes

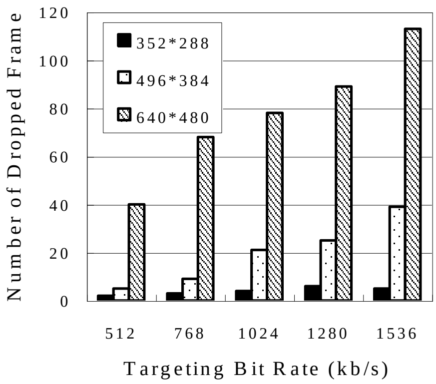

Figure 6. Average Numbers of Dropped Frame Depend on Difference Resolutions in Three Minutes

As shown in Figure 5 and Figure 6, no matter what frame size or packets, the average number of lost data becomes larger and larger with the increasing targeting bit rate. And at a given targeting bit rate, the larger the frame size, the more loss of data.

I frame and P frame are commonly two frame types in video compression. For I frames, the texture data in current frame is coded. But for P frames, the residual data is calculated and coded with the pixel difference between predicted reference frame and the current encoded frame. So the data after compression in I frames is more than data in P frames. As shown in Figure 7, the curves are obtained on the condition that the targeting bit rate is 1024Kbps and the period to I frame is 30. Because the period to I frame is 30, the first frame and the 31th frame were I frames, the others are P frames. It can be seen that the length of P frames has a little change at the center of one constant value (4500bytes), which leads the frame size do not impact the average compression rate (4500*8*30/1024=1054kbps). But the lengths of I frames are increased rapidly with the frame size going up.

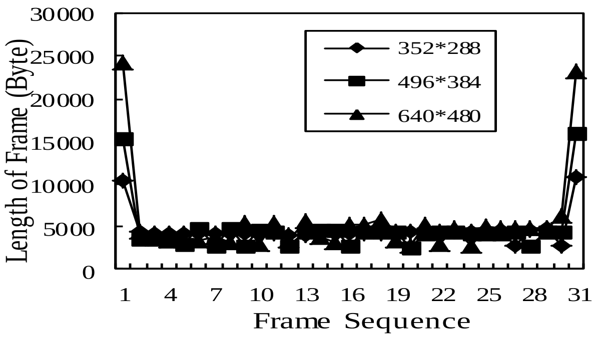

Figure 7. Average Lengths of I Frame and P Frame under the Targeting Bit Rate 1024Kbps

As we known, the peaking of video stream is occurred at I frame. Therefore, those data from L2CAP layer will be stored in service-manager buffer. If the buffer is not large enough, it may be full soon. As a result, the more bit-stream data in I frame, the more data lost.

3.3. Quality of Video

The acceptable picture quality of H.264 video is 384kbps for 352 pixels by 288 pixels picture size at 25frame/s. For large resolution, such as 640 pixels by 480 pixels pictures, it requires data rate about 1152kbps. From test 1, it is known that our system can support the maximum transfer data rate 1.6Mbps and this satisfied the requirement of bit-rate. But the quality of video after decoding is not only affected by stream-bit rate, but also by frame loss or dropped data. To Motion compensation for image sequence, correlation between successive frames of an image sequence should be considered. If one frame/packet is error or dropped, it will cause spatial and temporal error propagation as well as synchronization errors effect video quality. In test 2, the picture size 640 pixels by 480 pixels and service-manager buffer size is 200K Byte. When the targeting bit rate is more than 1024kbps under, the amount of lost data is large. So the quality of decoding video is poor, as is shown in Figure 8.

From these tests above, it could be concluded that the key video parameters for good video quality in our system can be set as following: the targeting bit rate should be set at less than 1024kbps, the maximum resolution is 640 pixels by 480 pixels, and the frame rate is 30frames/sec. Compared with the performance in paper [10] which adopts MPEG4 video transmission over Bluetooth 1.2, and frame size of 240 pixels by 180 pixels, the proposed scheme has a distinct competitive advantage in Image quality.

(a) Bit Rate =1024kbps (b) Bit Rate =1536kbps

Figure 8. Video Quality for 640*480 Pictures under Difference Compression Bit Rate

4. Conclusion

With increment of Bluetooth bandwidth, the video transmission over Bluetooth network is an emerging area. This paper proposes an optimized Qos control of video transmission system for mobile applications. The system has advantages of high transfer bit rates of H.264 video streams, adequate video quality and efficient resource management. And more, the suggested system design has good expansibility and portability, the Bluetooth component can easily be replaced by other transmission technology (such as IEEE 802.11) without changing the other parts. It could be applied to video conference, wireless video monitor and video player on portable devices *etc*.

References

[1] C. H. Chia and M. S. Beg, "Realizing MPEG4 Video Transmission over Wireless Bluetooth Link via HCI", IEEE Trans. Consumer Electronics, vol. 49, no. 4, **(2003)**, pp. 1028-1034.
[2] S. Pudlewski, T. Melodia and A. Prasanna, "Compressed-Sensing-Enabled Video Streaming for Wireless Multimedia Sensor Networks", IEEE TRANSACTIONS ON MOBILE COMPUTING, vol. 11, no. 6, **(2012)**, pp. 1060-1072.
[3] K. Salah; F. Al-Haidari; M. H. Omar; A. Chaudhry, "Statistical analysis of H.264 video frame size distribution", Communications, IET , vol. 5, no. 14, **(2011)**, pp. 1978 – 1986.
[4] W. Liu, Vijayanagar and K. R. Joohee Kim, "Low-complexity distributed multiple description coding for wireless video sensor networks", Wireless Sensor Systems, IET., vol. 3, no. 3, **(2013)**, pp. 205-215.
[5] T. Pering, Y. Agarwal, R. Gupta and C. Power, "CoolSpots: Reducing the Power Consumption of Wireless Mobile Devices with Multiple Radio Interfaces", Proc. ACM MobiSys, **(2006)**, pp. 220-232.
[6] P. Mohan, V.N. Padmanabhan, and R. Ramjee, "TrafficSense: Rich Monitoring of Road and Traffic Conditions Using Mobile Smartphones," Technical Report MSR-TR-2008-59, Microsoft, 2008.
[7] J.-C. Cano, J.-M. Cano, E. Gonzalez, C. Calafate, and P. Manzoni, "Power Characterization of a Bluetooth-Based Wireless Node for Ubiquitous Computing," Proc. IEEE Int'l Conf. Wireless and Mobile Comm.,p. 13, 2006.
[8] R. Razavi, M. Fleury, E. Jammeh and M. Ghanbari. "Efficient packetisation scheme for Bluetooth video transmission," ELECTRONICS LETTERS, 42(20), 1143-1145 (2006).
[9] Bin Sattar. R, Ahmed. N, and Rahman, M, "An Adaptive Approach for Video Streaming and Evaluation over Bluetooth Network," Wireless Communications, Networking and Mobile Computing (WiCOM), 1-4 (2012).
[10] Guillaume F. Remy, Hassan B. Kazemian, Phil, and PictonIvan, "Application of neural-fuzzy controller for streaming video over Bluetooth 1.2," Neural Comput & Applic 20(6):879–887 (2011).
[11] Bluetooth SIG. Specification of the Bluetooth System, Core Specifications, version 4.2 [S]. 2014.
[12] Corina Scheiter, Rainer Steffan, and Benno Stebernack, "A System foe QoS-Enabled MPEG4 Video Transmission over Bluetooth for Mobile Applications," IEEE International Conference on Multimedia & Expo, 789-792, (2003).
[13] Fantacci. R., Scardi. M, "Performance evaluation of preemptive polling schemes and ARQ techniques for indoor wireless networks," IEEE Trans. Veh. Technol. 248–257(1996).
[14] M. C. Valenti, M. Robert, and J.H. Reed, "On the throughput of Bluetooth data transmissions," IEEE Wireless Communications and Networking Conference. 119-123 (2002).
[15] Corina Scheiter, Rainer Steffan, and Benno Stebernack, " A System for QoS-Enabled MPEG4 Video Transmission over Bluetooth for Mobile Applications," IEEE International Conference on Multimedia & Expo, 789-792 (2003).

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