RELIABLE MULTIMEDIA TRANSMISSION OVER WIRELESS SENSOR NETWORK

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To my beloved father, Yunus Bin Othman, mother, Fatimah Binti Ngah and my sibling.

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ABSTRACT

Nowadays, video streaming application is widely used in wired as well as wireless environment. Extending this application into Wireless Sensor Networks (WSN) for IEEE 802.15.4 network has attracted lots of attention in the research community. Reliable data transmission is one of the most important requirements in WSN especially for multimedia application. Moreover, multimedia application requires high bandwidth and consumes large memory size in order to send video data that requires small end-to-end (ETE) delay. To overcome this problem, rate control serves as an important technique to control the bit rate of encoded video for transmission over a channel of limited bandwidth and low data rate which is 250kbps with small Maximum Transmission Unit (MTU) size of 127 bytes. Therefore, a rate control model called enhanced Video Motion Classification based (*e-ViMoC*) model using an optimal combination of parameter setting is proposed in this thesis. Another challenging task to maintain the video quality is the design of an enhanced transport protocol. Standard transport protocols cannot be directly applied in WSN specifically, but some modifications are required. Therefore, to achieve high reliability of video transmission, the advantages of User Datagram Protocol (UDP) features are applied to the proposed transport protocol called Lightweight Reliable Transport Protocol (LRTP) to tailor to the low data rate requirement of WSN. Besides, priority queue scheme is adopted to reduce the end-to-end delay while maintaining the reliability and energy efficiency. Evalvid simulation tool and exhaustive search method are used to determine optimal combination of quantization scale (q), frame rate (r) and Group of Picture (GOP) size (l) values to control the bit rate at the video encoder. The model of *e-ViMoC* is verified both with simulation and experimental work. The proposed transport protocol has been successfully studied and verified through simulation using Network Simulator 2 (NS-2). From the simulation results, the proposed *e-ViMoC* encoded video enhances the Packet Delivery Ratio (PDR) by 5.14%, reduces the energy consumed by 16.37%, improves the Peak Signal to Noise Ratio (PSNR) by 4.37% and reduces the ETE delay by 23.69% in average, compared to non-optimized encoded video. The tested experiment experiences slightly different result where the PDR is 6% lower than simulation results. Meanwhile, the combination of *e-ViMoC* and LRTP outperforms the standard transport protocol by average improvement of 142.9% for PDR, average reduction of 8.87% for energy consumption, average improvement of 4.1% for PSNR, and average reduction of 19.38% for ETE delay. Thus, the simulation results show that the combination of proposed *e-ViMoC* and LRTP provides better reliability performance in terms of the PDR while simultaneously improves the energy efficiency, the video quality and ETE delay.

ABSTRAK

Kini, aplikasi video digunakan secara meluas dalam persekitaran berwayar dan tanpa wayar. Meluaskan aplikasi ini ke Rangkaian Sensor tanpa Wayar (WSN) iaitu rangkaian IEEE 802.15.4 telah menarik banyak perhatian dalam komuniti penyelidikan. Penghantaran data yang boleh dipercayai adalah salah satu keperluan yang penting dalam WSN terutamanya untuk aplikasi multimedia. Lagipun, aplikasi multimedia memerlukan jalur lebar tinggi dan saiz memori yang besar untuk menghantar data video yang memerlukan kelewatan Hujung-ke-Hujung (ETE) yang kecil. Untuk mengatasi masalah ini, teknik kawalan kadar bit adalah penting untuk mengawal kadar bit penghantaran video melalui saluran jalur lebar yang terhad dan kadar data yang rendah iaitu 250kbps dengan Penghantaran Unit Maksimum (MTU) yang kecil iaitu 127 bit. Oleh itu, suatu kawalan kadar dinamakan model berdasarkan Klasifikasi Gerakan Video yang dibaikkan (*e-ViMoC*) menggunakan gabungan optimum tetapan parameter adalah dicadangkan di dalam tesis ini. Satu lagi tugas yang mencabar untuk mengekalkan kualiti video adalah menyediakan protokol penghantaran yang dipertingkatkan. Protokol standard tidak boleh diaplikasi terus secara spesifik di WSN tetapi memerlukan sedikit pegubahsuaian. Oleh itu, untuk mencapai kebolehpercayaan penghantaran data video yang tinggi, ciri kelebihan Protokol Datagram Pengguna (UDP) diaplikasikan untuk protokol pengangkutan yang dicadangkan iaitu Protokol Penghantaran Boleh-percaya Ringan (LRTP) untuk mematuhi kadar data WSN yang rendah. Selain itu, skim giliran keutamaan diguna pakai untuk mengurangkan kelewatan hujung-ke-hujung disamping mengekalkan kebolehpercayaan dan kecekapan tenaga. Penyelaku Evalvid dan kaedah carian terperinci digunakan untuk menentukan gabungan optimum nilai skala pengkuantuman (q), kadar kerangka (r) dan saiz kumpulan gambar (GOP) (l) untuk mengawal kadar bit semasa video dikodkan. Model *e-ViMoC* disahkan dengan penyelakuan dan eksperimen. Protokol penghantaran yang dicadangkan telah berjaya dikaji dan disahkan melalui simulasi menggunakan Penyelaku Rangkaian (NS-2). Daripada keputusan penyelakuan, video yang dikodkan dengan *e-ViMoC* meningkatkan Nisbah Penghantaran Paket (PDR) sebanyak 5.14%, mengurangkan tenaga yang digunakan sebanyak 16.37%, meningkatkan Nisbah Puncak Kuasa Hingar (PSNR) sebanyak 4.37% dan mengurangkan kelewatan ETE sebanyak 23.69% berbanding dengan video kod yang tidak dioptimumkan. Eksperimen tapak uji mengalami sedikit perbezaan keputusan di mana PDR adalah 6% lebih rendah daripada keputusan penyelakuan. Sementara itu, kombinasi *e-ViMoC* dan LRTP mengatasi protokol penghantaran standard dengan peningkatan purata sebanyak 142.9% untuk PDR, pengurangan sebanyak 8.87% bagi penggunaan tenaga, peningkatan sebanyak 4.1% bagi PSNR, dan pengurangan sebanyak 19.38% bagi kelewatan ETE. Maka, keputusan penyelakuan menunjukkan bahawa gabungan *e-ViMoC* dan LRTP menyediakan prestasi kebolehpercayaan yang lebih baik dari segi PDR, peningkatan kecekapan tenaga, kualiti video dan kelewatan ETE.

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LIST OF ABBREVIATIONS

AdamRTP	-	Adaptive Multi-flows Real-time
ADC	-	Analog to Digital Converters
AFX	-	Animation Framework eXtension
AIMD	-	Additive Increase and Multiplicative Decrease
ART	-	Asymmetric and Reliable Transport
ART	-	Adaptive Retransmission Trigger
AVC	-	Advanced Video Coding
B frame	-	Bidirectional frame
BO	-	Beacon Order
BS	-	Binary Search
CAP	-	Contention Access Period
CBR	-	Constant Bit Rate
CCA	-	Clear Channel Assessment
CCIR	-	International Radio Consultative Committee
CCTV	-	Closed Circuit Television
CD-ROM	-	Compact Disk – Read Only Memory
CFP	-	Contention Free Period
CIF	-	Common Intermediate Format
CLD	-	Cross Layer Design
CL-MGTS	-	Cross Layer Multimedia Guaranteed Time Slot
CMOS	-	Complementary Metal-Oxide Semiconductor
CN	-	Congestion Notification
CONSEQ	-	CONtrol of SEnsor Queue
CQ	-	Constant Quality
CSMA	-	Carrier Sense Multiple Access
CSMA/CA	-	Carrier Sense Multiple Access/ Collision Avoidance
DCT	-	Discrete Cosine Transform

DMIF	-	Delivery Multimedia Integration Framework
DWT	-	Discrete Wavelet Transform
eACK	-	Explicit Acknowledgement
eCMT	-	Environment Aware Concurrent Multipath Transfer
ETE	-	End to End
e-ViMoC	-	Enhanced Video Motion Classification Based
FCF	-	Frame Control Field
FCS	-	Frame Check Sequence
FEC	-	Forward Error Correction
FIFO	-	First In First Out
FLCQ	-	Frame-level Laplacian Constant Quality
fps	-	Frame per second
FSN	-	Frame Sequence Number
GFX	-	Graphical Framework eXtension
GOP	-	Group of Picture
GTS	-	Guarantee Time Slot
HDTV	-	High Definition Television
HOL	-	Head of Line
HQ	-	High Priority Queue
HR-WPAN	-	High Rate Wireless Personal Area Network
I frame	-	Intra frame
iACK	-	Implicit Acknowledgement
ID	-	Identification number
IEC	-	International Electrotechnical Commission
IEEE	-	Institute of Electrical and Electronic
IETF	-	Internet Engineering Task Force
INIT	-	Initialize the LRTP Packet
ISDN	-	Integrated Services for Digital Network
ISO	-	International Standard Organization
ITU	-	International Telecommunications Union
JPEG	-	Joint Photographic Expert Group
JVT	-	Joint Venture Team
LDPC	-	Low Density Parity Check

LLC	-	Logical Link Layer
LQ	-	Low Priority Queue
LRCC	-	Load Repartition Congestion Control
LRTP	-	Lightweight Reliable Transport Protocol
LRTPAck	-	Lightweight Reliable Transport Protocol Acknowledgement
LR-WPAN	-	Low Rate Wireless Personal Area Network
LR-WPAN	-	Low Rate Wireless Personal Area Network
LSRP	-	Link State Routing Protocol
MAC	-	Medium Access Control
M-DTSN	-	Multimedia Distributed Transport for Sensor Network
MMDR	-	Multipath Multi-stream Distributed Reliability
MOS	-	Mean Opinion Score
MPEG	-	Moving Picture Expert Group
MPEG-TFRCP	-	MPEG TCP-Friendly Rate Control Protocol
MPMPS	-	Multi-priority Multi-path Selection
MRTP	-	Multiflow Real-time Transport Protocol
MR-WPAN	-	Medium Rate Wireless Personal Area Network
MSE	-	Mean Square Error
MTU	-	Maximum Transmission Unit
NACK	-	Negative Acknowledgement
NEC	-	Normalized Energy Consumption
NS-2	-	Network Simulator 2
NTSC	-	National Television Standard Committee
OF	-	Optimal Forwarding
OSI	-	Open System Interconnection
P frame	-	Predicted frame
PAL	-	Phase Alternating Line
PAN	-	Personal Area Network
P-ARQ	-	Priority Automatic Request Queue
PC	-	Pearson’s Correlation
PCC-PRG	-	Priority Based Congestion Control and Partial Reliability

		Guaranty
PDR	-	Packet Delivery Ratio
PQM	-	Path Quality-aware Model
PR	-	Partial Reliability
PR	-	Packet Received
PRR	-	Packet Reception Rate
PS	-	Packet Sent
PSDU	-	Physical Service Data Unit
PSNR	-	Peak Signal to Noise Ratio
PSTN	-	Public Switched Telephone Network
QCCP-PS	-	Queue based Congestion Control Protocol with Priority Support
QCIF	-	Quarter Common Intermediate Format
QM/BM	-	Quality/ Bit Matching
QoS	-	Quality Of Service
RAIT	-	Reliable Asynchronous Image Transfer
RAM	-	Random Access Memory
RCCP	-	Receiver Congestion Control Protocol
RC-VBR	-	Rate Control Variable Bit Rate
R-D	-	Rate Distortion
R-Q	-	Rate Quantization
RMSE	-	Root Mean Squared Errors
RMST	-	Reliable Multi-Segment Transport
ROI	-	Region of Interest
RSTP	-	Reliable Synchronous Transport Protocol
RTLD	-	Real-time with Load Distribution
RTS/CTS	-	Request to Transmit/Clear to Transmit
RTT	-	Round Trip Time
SACK	-	Selective Acknowledgement
SCAP	-	Source Congestion Avoidance Protocol
SCTP	-	Stream Control Transmission Protocol
SD	-	Superframe Duration
SDTV	-	Standard definition TV

SIF	-	Source Input Frame
SO	-	Superframe Order
SQCIF	-	Sub Quarter Common Intermediate Format
SSN	-	Stream Sequence Number
SUIT	-	Sensor fUzzy-based Image Transmission
TCP	-	Transmission Control Protocol
TDMA	-	Time Division Multiple Access
TEC	-	Total Energy Consumed
TES	-	Transform Expand Sample
TFCC	-	Trust Based Fuzzy Algorithm for Congestion Control
TM	-	Trust Metrics
TM5	-	Test Model version 5
TMN8	-	Test Model Near-term version 8
TX-HIGH	-	Transmit High Priority Data
TX-LOW	-	Transmit Low Priority Data
UDP	-	User Datagram Protocol
UWB	-	Ultra Wide Band
VBR	-	Variable Bit Rate
ViMoC	-	Video Motion Classification Based
VLC	-	Variable Length Coding
VOP	-	Video Object Plane
WCCP	-	Wireless Multimedia Sensor Network Congestion Control Protocol
WLAN	-	Wireless Local Area Network
WMSN	-	Wireless Multimedia Sensor Network
WPAN	-	Wireless Personal Area Network
WSN	-	Wireless Sensor Network

LIST OF SYMBOLS

q	-	Quantization scale
r	-	Frame rate
l	-	Group of Picture (GOP) length
$B(q, r)$	-	ViMoC model for parameter setting of quantization scale and frame rate
B_{max}	-	Maximum bit rate with the combination of minimum quantization scale and maximum frame rate
$B_q(q, r_{max})$	-	Normalized bit rate versus quantization scale
$B_r(r, q)$	-	Normalized bit rate versus frame rate
$B_q(q)$	-	Normalized bit rate versus quantization scale represent the function of q only
$B_r(r)$	-	Normalized bit rate versus frame rate represent the function of r only
$B'(q, r, l)$	-	e-ViMoC model for parameter setting of quantization scale, frame rate and GOP size
B'_{max}	-	Maximum bit rate with the combination of minimum quantization scale, maximum frame rate and maximum GOP size
$B'_q(q; r_{max}, l_{max})$	-	Normalized bit rate versus quantization scale, for the maximum frame rate, and maximum GOP size
$B'_r(r; q, l_{max})$	-	Normalized bit rate versus frame rate, for the given quantization scale and maximum GOP size
$B_l(l; q, r)$	-	Normalized bit rate versus GOP size, for the given quantization scale and frame rate

$B_l(l)$	-	Normalized bit rate versus GOP size, for the given quantization scale and frame rate represent the function of *l* only
FL_T	-	Frame loss based on frame type
nT_{recv}	-	The number of type *T* frames received
nT_{sent}	-	The number of type *T* frames sent
n	-	Packet number
r_n	-	The time that data packet *n* was sent
s_n	-	The time that data packet *n* was received
$X(i,j)$	-	The original or reference source frame
$Y(i,j)$	-	Reconstructed frame

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CHAPTER 1

INTRODUCTION

1.1 Background

Recent advances in wireless communication technology, digital electronics and micro-electro-mechanical systems have enabled the development of low-cost, low-power and small size of sensor nodes which can communicate within short distances [1]. These sensor nodes consist of sensing, data processing and wireless communicating component. The sensor nodes can be transmitted information or data collected wirelessly to the base station and are interconnected to form a network which is defined as Wireless Sensor Network (WSN). WSN is generally built up from hundreds or thousands of sensor nodes. During the last few years, WSN has significant importance in monitoring changes of environmental parameters such as temperature, sound, vibration, pressure and motion at different locations. In typical WSN, sensor nodes have constraints in energy consumption, limited memory resources and processing capability [2].

One of the most famous standards with possible deployment of WSN is IEEE 802.15.4. The IEEE 802.15.4 [3] defines a data communication protocol standard for the physical and Media Access Control (MAC) layers of low rate wireless personal area networks (LR-WPAN). The features of LR-WPAN are ease of installation and deployment, reliable data transfer, short-range communication, low cost, reasonable battery life while maintaining a simple and flexible protocol stack [4].

The main aim of any WSN deployment is to ensure reliable communication between source and destination which is the probability of packet being received at the destination [5]. Reliability is one of the important criteria for evaluating the quality of WSN which give significant impact on the network performance such as delivery ratio, energy consumption and end-to-end delay. Reliability will be affected by parameters such as channel quality, information congestion, and size of the packet transmission. Reliability in WSN is basically depends on various factors such as hardware constraint, deployment strategy, wireless link characteristics and environmental conditions. These factors are crucial in order to ensure that the network can support the application requirement.

As mentioned before, sensor nodes have constraints in energy consumption, limited memory resources and processing capability. Because of these hardware constraints, there is an effort to reduce the cost of the sensors node which results in allowing massive deployment [6] [7]. Thus, sensors are densely deployed to increase the sensing coverage, connectivity and to prolong the network lifetime [8]. However, energy constraint will limit the range of communication. Other challenge in achieving reliability in WSN is the nature of wireless communication link. The problem of achieving reliable communication between nodes in WSNs is further aggravated by the presence of wireless link with higher bit-error rate [9]. Since the WSN communication bandwidth is small, overhead for error correction cannot be added to the data packet. As a consequence, the characteristic of wireless communication links will degrade the reliability performance of the network. Environmental conditions are also one of the challenges to achieve the reliability in WSN. The environmental conditions such as physical, chemical and biological factors will directly affect the sensing unit and wireless transceiver of a sensor node. Even though the condition of the hardware is good, but the communication between nodes may be affected by environmental factors, which decreases the reliability performance of the network.

Recently, multimedia applications over WSNs are emerging rapidly. This is due to the advancement of wireless multimedia services and technologies such as wireless video services which are becoming ubiquitous in our daily life [10].

Therefore, there is an increasing interest in the research community to design and develop critical services that require video monitoring over WSNs. The WSNs with multimedia application are focusing from typical scalar data such as temperature, humidity, pressure and light to multimedia data. For the purpose of multimedia data transmission, the networks consist of multimedia devices that are capable to send video and images as well as scalar data. With the existing WSNs for multimedia transmission, many potential applications can be provided such as multimedia surveillance sensor network, traffic control system to avoid traffic congestion, law enforcement report, environmental monitoring for habitat monitoring, industrial process control to detect defective products automatically and advanced health care delivery [11]. All of these multimedia applications have the potential of enhancing the level of collective information, increasing the range of coverage and allowing many resolution views [12].

Enabling multimedia application requires additional characteristics and challenges due to the nature of multimedia data such as high bandwidth demand, multimedia coding technique, power consumption, application-specified Quality of Service (QoS) requirement, tolerable end-to-end delay and proper jitter [11]. However, these requirements contradict with the characteristic and challenges of sending multimedia data over WSNs mentioned earlier which are limited storage, limited processing ability and bandwidth limitations of sensor nodes. These factors are important as a guideline to design communication protocols for efficient multimedia transmission in sensor networks which comply to the IEEE 802.15.4 standards. Therefore, reliable data transmission in WSNs becomes very crucial for multimedia application with different application requirements.

Multimedia application requires reliable data transfer during encoding process, during transmission over WSN and also during decoding process. Particularly, the most important processes of video transmission are during the encoding process and transmission over WSN. This is because these processes will have significant effect on the results at the end of data transmission. Therefore, to provide reliable transmission, the research focuses on the video encoding process and designing efficient transport protocol in WSN.

The video encoding process is crucial in reducing the traffic volume for transmission as well as maintaining the quality of video. Rate control is one of the ways to reduce the size of bandwidth requirement for video transmission over sensor networks. The rate control is an important technique to control the bit rate of video transmission over a channel of limited bandwidth. This technique must be employed during the video compression process in order to adjust the encoding parameter settings and ensure that the video bit rate meets the requirement of WSN characteristic which is less than 250kbps.

Besides, to improve reliability, to meet the application QoS requirement, as well as to provide a fair and efficient technique to cater the resource constraints, other issues of reliability and characteristics of multimedia application have become a concern and need to be considered properly at different layer of communication protocols stack in WSN. Reliability can be provided at the network layer [13], [14], [15], [16] and transport layer. However, most of the researchers consider provision of reliability at the transport layer as discussed in [17]. It is understood that reliable data transmission in WSN is very crucial for multimedia application such as video transmission. Thus, implementation of transport protocol in WSN for multimedia application is a challenging task. A standard transport protocol such as User Datagram Protocol (UDP), Transmission Control Protocol (TCP) and Stream Control Transmission Protocol (SCTP) are extensively used in Internet but can be applied for multimedia application over WSN with some modifications to tailor with the characteristics of multimedia and WSN. Therefore, multimedia transmission requires a enhanced transport protocol that meets all the requirements to run the application despite the limitations of sensor nodes and the unique characteristics of multimedia communication. The main goal of the enhanced transport protocol is to transmit video data over WSN in a promising way to achieve good data transmission reliability and energy efficiency to extend the network lifetime. It is also required to provide congestion control mechanism in order to ensure good video quality.

1.2 Problem Statement

Recently, advancement in wireless access network, especially for wireless multimedia services is becoming ubiquitous in our daily life. Therefore, reliable data transmission in wireless network is very crucial for multimedia application. This is because for multimedia application, large bandwidth and huge memory are required in order to send the video data and ensure that the video received is in good quality.

IEEE 802.15.4 standard [3] that has the characteristics of low data rate transmission, low energy consumption, ease of deployment and low cost has attracted lots of attention in the research community. However, due to the low transmission rate up to 250kbps [3] with small Maximum Transmission Unit (MTU) size of 127 kbytes [18] supported by IEEE 802.1.5.4 and the characteristic possessed by wireless networks (channel quality, traffic congestion) high traffic data such as video transmission over WSN imposes new research issues and challenges. Based on related literature, video transmission mainly focuses on high data rate standards such as WiFi, Bluetooth and other technologies which support data rate in Mbps with MTU up to 1500 bytes. Thus, video transmission over IEEE 802.15.4 network is more challenging and is given a special interest due to its nature of low complexity and low implementation cost, but is still capable of maintaining good received video quality.

In video transmission, the video bit rate are important criteria that need to be considered to ensure the video can be transmitted over WSN because high video bit rate will produce large video file size. Large video size requires a lot of fragmentation to generate an optimal packet size. In WSN, the number of packet transmission is an important parameter which will influence the reliability and energy consumption. Large number of packet transmission will result in high packet error rate [19][20] and increase the number of retransmission as well as energy consumption [19] [21]. Moreover, the video received will be corrupted due to packet loss and corruption of some of the important video frames during the transmission. Rate control [22] is one of the ways to reduce the traffic volume for transmission over limited bandwidth by controlling the video size and video bit rate as well as maintaining the quality of video during the video encoding process. Most of the previous work on multimedia application focuses on network that support high data rate, thus large video size is not an issue. In order to achieve reliable video transmission, the rate control technique must be employed during the video compression process in order to adjust the encoding parameter settings and ensure that the video bit rate and video size meets the requirement of WSN characteristic.

Another challenging task to achieve reliable video transmission in WSN as well as to maintain the video quality is the consideration of communication protocols stack which is the transport protocols. Transport protocol works at transport layer that responsible to ensure end-to-end reliability, which is the probability of packets being received at the destination and to provide congestion control mechanism to reduce or alleviate any congestion happen. The standard transport protocols such as UDP, TCP and SCTP can be applied in WSNs with some modifications to tailor with the limitation of WSN [11]. Meanwhile, most of the existing non-standard transport protocols do not considered the problem of solving the high bandwidth demand with low power consumption because the protocols are applied at network that support high data rate [23]. Thus, to achieve high reliability for video transmission over the network of IEEE 802.15.4 standard, the modification of standard transport protocol will be adopted in the proposed enhanced transport protocol to provide lightweight protocol. Since energy is very crucial in WSN, the proposed enhanced transport protocol algorithm will also consider the problem of high power consumption in transmitting multimedia data. Thus, to prolong the lifetime of a wireless sensor node, an efficient transport protocol needs to support reliable message delivery and congestion control with energy efficiency. During data transmission, rate adjustment which is the sending rate from the sender will be reduced when congestion is detected.

1.3 Objectives of the Research

The primary goal of this research is to provide reliable multimedia data transmission over Wireless Sensor Network (WSN) as well as to satisfy the Quality of Service (QoS) demand for multimedia communication. The QoS demand is in terms of packet delivery ratio (PDR), peak signal to noise ratio (PSNR), end-to-end (ETE) delay and throughput of the network with the constraints of WSN which are limited bandwidth, battery power and small memory size. The specific objectives of the proposed design are:

- To determine the optimum value for quantization scale, frame rate and Group of Picture (GOP) size for video encoding process
- To enhance variable rate control model for video encoding process
- To develop a suitable transport protocol in order to achieve end-to-end reliability for video transmission over WSN

1.4 Scope of the Research

This research work focuses on designing reliable data transmission that is highly subjected to minimize the number of packet loss for multimedia application. Therefore, reliable data transmission needs to be ensured during the video encoding process and during the video transmission in the wireless network.

During video encoding process, bit rate control technique is required to reduce the video bit rate in order to meet the requirement of WSN limited bandwidth. The video bit rate is controlled by determine the optimal and accurate combination of parameter settings. The parameters taken into consideration are quantization scale (q), frame rate (r) that measured in term of frame per second (fps) and the size of Group of Picture (GOP) (l). MPEG-4 video codec is one of the compression schemes that was identified to be suitable for WSN environment. In this work, a simulation study for MPEG-4 video encoding scheme based on an experimental model was carried out to determine conformance with IEEE 802.15.4 requirements. The video samples will be encoded and decoded in offline mode due to the complexity of encoding and decoding process where the results produced would be used for simulating the wireless scenario in the simulator.

In addition, to improve the reliability of video transmission over WSN, an enhanced transport protocol is proposed. In transport protocol, reliability for multimedia application can be achieved by preventing unnecessary retransmission and prioritize data depending on the importance of video data (I frame and P frame) in the network using priority queue. Besides, transport protocol also provides congestion control mechanism to avoid any congestion that may happen in the network. Reliable message delivery in an energy efficient manner is needed because the sensor node has limited operating lifetime. Due to the limited transmission capacity of sensor nodes, the frames are fragmented into 100 bytes for energy efficiency purposes.

The physical layer characteristic is based on IEEE 802.15.4 standard. This standard provides low data rate (limited bandwidth) which is 250kbps with small MTU size of 127 bytes. The unslotted Carrier Sense Multiple Access/ Collision Avoidance (CSMA/CA) is adopted in MAC layer and Real-Time Load Distribution (RTLD) routing protocol is adopted as a routing protocol in the network layer. The standard transport protocols which are User Datagram Protocol (UDP), Transmission Control Protocol (TCP) and Stream Control Transmission Protocol (SCTP) are used at transport layer. The network topology is set up with grid topology for multi-hop network to ensure that the coverage area between each node is same. The assumptions of this research are node is assumed to be static and the network is limited to small size network which the number of nodes is less than 100.

In this research, Evalvid simulation tool set and Cgywin window are used to encode the video during the encoding process. Then, the proposed bit rate control model is computes based on the video bit rate from the video encoding process in order to ensure the bit rate is less than 250kbps with the packet size of transmission is 127kbytes. Finally, the simulation of encoded video over WSN using Network Simulator-2 (NS-2) is verified with an experimental test bed data. In addition, the proposed enhanced transport protocol is developed and simulation study is carried out using Network Simulator-2 (NS-2). The simulation result is compared with the standard transport protocol in wireless sensor network for multimedia application.

1.5 Research Contribution

In this work, reliable data transmission needs to be assured during video encoding process and during data transmission. The proposed idea is to ensure quality of services (QoS) of video transmission in WSNs. The research contributions of this thesis are as follows:

1.5.1 Bit rate control for video encoding process

As mentioned earlier, the maximum data rate that is allowed in IEEE 802.15.4 standard is less than 250kbps. Therefore, if the video is not compressed with optimal parameter setting during video encoding, it will lead to the problem of buffer overflowing and will result in low video quality. The compressed video with optimal parameter setting during video encoding can reduce the packet loss while increasing the packet delivery ratio as well as enhancing the video quality. The simple procedures proposed for optimal parameter setting make it practical to be implemented in the video encoding process. The variable bit rate control model called Video Motion Classification Based (*ViMoC*) is proposed to predict and control the video bit rate at the encoder part. *ViMoC* model is derived from the simulated data which is based on the analysis of the effect of quantization scale (q) and frame rate (r) parameter setting variation towards video bit rate. Subsequently, enhanced ViMoC (*e-ViMoC*) model is proposed to further improve the previous model by incorporating the factor of GOP size, l. This is to ensure that the video bit rate meets the requirement of WSN characteristic without compromising the quality of the video during the encoding process.

1.5.2 Lightweight Reliable Transport Protocol (LRTP)

The LRTP is proposed with reliability and congestion control algorithm to achieve end-to-end reliable video transmission in WSN. The proposed LRTP protocol will adopted the some features of UDP with consideration for both requirements of sensor node characteristic and multimedia data communication. Besides, the LRTP will also adopt the priority queue which is giving high priority to I frame compared to others data. This priority scheme is crucial in order to enhance the energy efficiency by decreasing the number of retransmissions and end-to-end delay as well as packet lost.

1.6 Significance of the Research

In practical, video transmission over WSN is used to enhance and complement the existing sensor network application. As such, it is crucial to keep the cost of the sensor node and its power profile low by only transmitting a highly compressed video. Due to the low rate and small MTU size of IEEE 802.15.4 standard, video encoding process is essential as to maintain the quality of video as well as to reduce the traffic volume for transmission. By using MPEG-4 video compression technique, the cost for video transmission and energy consumption will be reduced. This will result in increasing the reliability performance of the WSN. Flood monitoring in remote area is an example of video transmission over WSN that requires low resolution video which is delay tolerant.

Besides, in wireless communication, the common factors that contribute to the packet loss in the network are unreliable wireless link, congestion in the network due to high number of packet transmission and channel bit error during data transmission. Therefore, the proposed transport protocol that provides reliable data transfer and congestion control mechanism can be used for multimedia application that requires reliability assurance. For example, the system that monitors different environment such as video surveillance in difficult access zone or dangerous places requires high reliability and less power consumption for longer lifetime. On the other hand, health monitoring for critical patient requires high reliability to ensure that fast action can be taken during the critical condition to safe the patient in short period of time.

1.7 Thesis organization

This thesis consists of six chapters which includes the three main contributions of the research. The background, problem statement, objectives, scope and contributions of the research are presented in Chapter 1.

Chapter 2 highlights the wireless sensor network for multimedia support, the video coding standard, compression techniques, rate control in video encoding, the literature review of video transmission over WSN and the transport protocol in WSNs. The review of transport protocols is also included the standard and non-standard transport protocol.

Chapter 3 primarily focuses on the design and architecture of the enhance variable rate control model for video encoding process and proposed transport protocol framework. The proposed rate control model and transport protocol are described in detailed using flowcharts and block diagrams. In addition, this chapter also includes the processes involved in network simulations, the parameter configurations and also the performance metrics used.

Chapter 4 presents the details on the first contribution which is the proposed rate control model for the video encoding process. This chapter includes description of process to choose the optimal setting of three parameters namely quantization scale, frame rate and Group of Picture (GOP) size followed by simulation study of video transmission over WSNs. Then, the results of the analysis and simulation are presented and discussed.

The second contribution which is LRTP is presented in chapter 5. The proposed transport protocol is explained, including reliability and congestion control. Reliability of video transmission in WSNs is further enhanced with priority queue. The performance of transport protocol is determined and discussed comprehensively.

The thesis concludes in Chapter 6. This chapter also provides the recommendations for the future work as directions for extension and enhancement of the contributions of this thesis.

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