HYBRID MEDIUM ACCESS CONTROL USING TOKEN APPROACH IN WIRELESS SENSOR NETWORK FOR HIGH TRAFFIC APPLICATIONS

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A thesis submitted in fulfilment of the
requirements for the award of the degree of
Doctor of Philosophy (Electrical Engineering)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

JULY 2015

To my beloved father, Ismail bin Kasim, mother, Maimun Binti Seman, my lovely auntie and uncle, Khadijah Binti Othman and Mohd Zain, my siblings, my cousins and my true friends

ACKNOWLEDGEMENT

Alhamdulillah, In the Name of Allah, the Most Beneficent and the Most Merciful. I am grateful to Allah for granting us faith, strength, good health and only by His guidance I can completed my research and this thesis.

I would like to express my sincere gratitude to my supervisor, Prof. Madya. Dr. Syarifah Hafizah Syed Ariffin for her guidance, advice, encouragement and full support throughout the accomplishment of this research works. She is a kind-hearted and patience supervisor. Without her continuous support and motivation, this thesis would not be completed well. I also want to thanks my co-supervisor, Dr. Nurul Mu'azzah Binti Abdul Latiff for constructive comments which her provided.

Recognition and thankfulness to all my colleagues and fellow researchers in UTM-MIMOS Center of Excellence for all of their helps, advice and encouragement at all the times up to completion of this research works. My special thanks to my lovely friends Farizah, Aimi, Azida, Wangi, Nurul, Ain, Fauzun, Nazirah and all those who have contributed, review and give a good feedback in realizing this research works.

Finally, I would like to express my deepest appreciation to my dearest family; my parents, Ismail bin kasim and Maimun binti Seman, my auntie, my uncle, my siblings, and my cousins for their constant love, encouragement and support which has been my source of inspiration, motivation and strength. I am indebted to all these important peoples in my life.

ABSTRACT

The evolution of Wireless Sensor Network (WSN) has experienced rapid growth in communication technology. Multimedia is a type of data needed in many applications of WSN. The existing WSN which runs on IEEE 802.15.4 standard mainly deals with low scalar traffic applications such as monitoring of temperature, humidity and pressure. Thus, high traffic application especially video transmission over WSN introduces huge challenges such as dynamic channel conditions, limited resources and delay constraint. The primary objective of this research is to develop reliable Medium Access Control (MAC) protocol that can maintain good quality of service (QoS) with low power consumption for high traffic application. The MAC layer design with token approach protocol namely MAC-TA protocol is proposed for single hop network. The Hybrid MAC namely HMAC-TA which is a combination of Carrier Sense Multiple Access (CSMA) and token approach protocol is proposed for multi-hop network. Both protocols are designed for high traffic scalar data. Then, the HMAC-TA protocol is enhanced to support MPEG-4 video transmission in WSN and the improved protocol is called eHMAC-TA. The proposed MAC protocols ensure low energy consumption by providing a reliable link for data transmission and minimizing the retransmission of packet loss. A cross layer design between MAC and routing protocol is used in token passing decision to ensure the channel is fully utilized by the node that has data to transmit. The token packet is regenerated based on two hops neighbour calculations to avoid token collision. The proposed MAC protocol has been successfully studied and verified through simulation. The eHMAC-TA protocol is verified both with simulation and experimental work. The network performance is measured in terms of packet delivery ratio (PDR), energy consumption and end-to-end (ETE) delay. Additionally for video analysis, peak signal to noise ratio (PSNR) performance is evaluated. Simulation results for single hop network show that MAC-TA protocol is able to maintain the PDR above 90%. This protocol also achieves lower energy consumption by 22.78 Joule, and reduces the ETE delay by 38 ms when compared with existing MAC protocols. The HMAC-TA protocol also outperforms the existing MAC in multi-hop network as it reduces energy consumption by 44%, improves PDR up to 21.39% and reduces ETE delay by 6.97 s. For video analysis using eHMAC-TA protocol, only low motion video is applicable to be transmitted in IEEE 802.15.4 medium when compared to high and medium motion. The simulation results show that eHMAC-TA protocol achieves high PDR which is above 90% and good video quality with PSNR higher than 31 dB compared to existing hybrid MAC protocol. The testbed experiment experiences slightly different result where the PDR is 10% lower than the simulation results. The proposed MAC protocol with token protocol has significantly enhanced the network performance for video application in WSN.

ABSTRAK

Evolusi Rangkaian Pengesan Wayarles (WSN) telah mengalami pertumbuhan yang pesat dalam bidang teknologi komunikasi. Multimedia adalah sejenis data yang diperlukan di dalam banyak aplikasi WSN. WSN yang sedia ada menggunakan piawai IEEE 802.15.4 kebanyakannya menjalankan aplikasi trafik skala rendah seperti pemantauan suhu, kelembapan dan tekanan. Oleh itu, aplikasi trafik yang tinggi terutamanya penghantaran video melalui WSN memberi cabaran besar seperti keadaan saluran dinamik, sumber terhad dan kekangan kelewatan. Objektif utama kajian ini adalah untuk membangunkan protokol Kawalan Akses Medium (MAC) yang dipercayai dapat mengekalkan perkhidmatan yang berkualiti (QoS) dengan penggunaan tenaga rendah bagi aplikasi trafik yang tinggi. Lapisan reka bentuk MAC dengan pendekatan token dinamakan protokol MAC-TA dicadangkan untuk rangkaian satu lompatan. Hibrid MAC dinamakan HMAC-TA adalah kombinasi Capaian Berbilang Deria Pembawa (CSMA) dan pendekatan token dicadangkan untuk rangkaian banyak lompatan. Kedua-dua rangkaian di reka untuk data trafik berskala tinggi. Kemudian, protokol HMAC-TA ditingkatkan untuk menyokong penghantaran MPEG-4 video di dalam WSN dan protokol yang ditambah baik dinamakan eHMAC-TA. Protokol MAC yang dicadangkan memastikan penggunaan tenaga yang rendah dengan menyediakan pautan yang dipercayai untuk penghantaran data dan mengurangkan penghantaran kembali paket yang hilang. Reka bentuk silang lapisan antara protokol MAC dan laluan digunakan di dalam keputusan penghantaran token untuk memastikan saluran diguna sepenuhnya oleh nod yang mempunyai data untuk dihantar. Paket token dihasilkan semula berdasarkan pengiraan dua nod lompatan berjiran bagi mengelakkan pertembungan token. Protokol MAC yang dicadangkan telah berjaya dikaji dan disahkan melalui simulasi. Protokol eHMAC-TA disahkan dengan simulasi dan eksperimen. Prestasi rangkaian diukur dari segi nisbah penghantaran paket (PDR), penggunaan tenaga dan kelewatan hujung-ke-hujung (ETE). Tambahan untuk analisa video, nisbah puncak kuasa hingar (PSNR) dinilai. Keputusan simulasi untuk rangkaian satu lompatan menunjukkan protokol MAC-TA dapat mengekalkan PDR lebih 90%. Protokol ini juga mencapai penggunaan tenaga yang rendah dengan 22.78 Joule, dan mengurangkan kelewatan ETE sebanyak 38 ms apabila dibandingkan dengan protokol MAC sedia ada. Protokol HMAC-TA juga mengatasi MAC sedia ada di dalam rangkaian banyak lompatan dengan mengurangkan penggunaan tenaga sebanyak 44%, meningkatkan PDR sebanyak 21.39% dan mengurangkan kelewatan ETE sebanyak 6.97 s. Untuk analisa video menggunakan eHMAC-TA, hanya video pergerakan perlahan yang boleh dihantar melalui media IEEE802.15.4 apabila dibandingkan dengan pergerakan laju dan sederhana. Keputusan simulasi untuk penghantaran video menunjukkan protokol eHMAC-TA mencapai PDR yang tinggi iaitu lebih 90% dan kualiti video yang baik dengan PSNR tinggi dari 31 dB apabila dibandingkan dengan protokol hibrid MAC sedia ada. Eksperimen tapak uji mengalami sedikit perbezaan keputusan di mana PDR adalah 10% lebih rendah daripada keputusan simulasi. Protokol MAC yang dicadangkan dengan pendekatan token telah meningkatkan prestasi rangkaian dengan ketara untuk penghantaran video.

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LIST OF ABBREVIATIONS

ACK	-	Acknowledgement
AI-LMAC	-	Adaptive, Information-Centric and Lightweight MAC
AMPH		Adaptive MAC Protocol for Heterogeneous
ARQ	-	Automatic Repeat Request
AVC	-	Advanced Video Coding
ASF	-	Advanced Systems Format
a-RtsCts-CSMA/CA	-	Adaptive Adoption Request to send Clear to send Carrier sense Multiple Access/ Collision Avoidance
BE	-	Back Off Exponent
BI	-	Beacon Interval
BO	-	Beacon Order
CAP	-	Contention Access Period
CBR	-	Constant Bit Rate
CCA	-	Clear Channel Assessment
CCTV	-	Closed Circuit Television
CD-ROM	-	Compact Disk – Read Only Memory
CFP	-	Contention Free Period
CIF	-	Common Intermediate Format
CL-MGTS	-	Cross Layer Multimedia Guarantee Time Slot
CMOS	-	Complementary Metal-Oxide Semiconductor
CODEC	-	Coder and Decoder
CSMA	-	Carrier Sense Multiple Access
CSMA/CA	-	Carrier Sense Multiple Access/ Collision Avoidance
CW	-	Contention Window
DRAND	-	Distributed Randomized Time Slot Assignment Algorithm

DynaMAC	-	Mobility Adaptive Real-Time TDMA MAC
ECG	-	Electrocardiogram
eHMAC-TA	-	Enhance Hybrid MAC With Token Approach
eL-MAC	-	Enhanced Lightweight Medium Access Control
ER-MAC	-	Emergency Response Mac
ESTR	-	Energy Saving Token Ring
ETE	-	End to End
FDMA	-	Frequency Division Multiple Access
FPS	-	Frame Per Second
GOP	-	Group Of Picture
GTS	-	Guarantee Time Slot
HDTV	-	High Definition Television
HMAC-TA	-	Hybrid MAC With Token Approach
IEEE	-	Institute of Electrical and Electronic Engineers
ISO	-	International Standard Organization
ISM	-	Industrial, Scientific And Medical
ITU	-	International Telecommunications Union
JVT	-	Joint Venture Team
JFR	-	Job Failure Rate
LEACH	-	Low Energy Adaptive Clustering Hierarchy
LLC	-	Logical Link Layer
LMAC	-	Lightweight Medium Access Control
LOS	-	Line-of-Sight
LR-WPAN	-	Low Rate Wireless Personal Area Network
MAC-TA	-	Medium Access Control With Token Approach
MH-TGM	-	Multi-Hop Token Generate Mechanism
MH-TPM	-	Multi-Hop Token Passing Mechanism
MH-TRM	-	Multi-Hop Token Recovery Mechanism
MEMAC	-	Mobility Aware And Energy Efficient MAC
MOS	-	Mean Opinion Score
MPEG	-	Moving Picture Expert Group
MTU	-	Maximum Transfer Unit
NACA	-	New Adaptive CSMA/CA Algorithm

NB	-	Number of Backoff
NBE-CSMA	-	Non Beacon Enable – Carrier Sense Multiple Access
NS2	-	Network Simulation 2
NCT	-	Node Control Token
NTH	-	Next Token Holder
OFC	-	Optimal Forwarding Choice
OSI	-	Open System Interconnection
PAN	-	Personal Area Network
PB	-	Period Boundary
PHY	-	Physical
PPDU	-	Physical Protocol Data Unit
PRR	-	Packet Reception Rate
PSDU	-	Physical Service Data Unit
PSNR	-	Peak Signal To Noise Ratio
QCIF	-	Quarter Common Intermediate Format
QoS	-	Quality of Service
QS	-	Quantization Scale
RAM	-	Random Access Memory
RSSI	-	Received Signal Strength Indicator
RTH-MAC	-	Real Time Hybrid Mac
RTLD	-	Real-Time Load Distributed
RTR	-	Request To Route
RTS/CTS	-	Request To Send/Clear To Send
SD	-	Superframe Duration
SDTV	-	Standard Definition TV
SEHM	-	Scalable and Energy Efficient Hybrid-Based MAC
SH-TGM	-	Single Hop Token Generate Mechanism
SH-TPM	-	Single Hop Token Passing Mechanism
SH-TRM	-	Single Hop Token Recovery Mechanism
SNR	-	Signal-To-Noise Ratio
SO	-	Superframe Order
TACK	-	Token Acknowledgement
TAMsg	-	Token Alert Message

TLMsg	-	Token Level Message
TSMsg	-	Token Schedule Message
TPMsg	-	Token Passing Message
TG1	-	Token Generated 1
TG2	-	Token Generated 2
TCP/IP	-	Transmission Control Protocol/Internet Protocol
TDMA	-	Time Division Multiple Access
TH-MAC	-	Three-Jump Hybrid Mac
THT	-	Token Holding Time
TST	-	Token Schedule Table
UDP	-	User Datagram Protocol
WLAN	-	Wireless Local Area Network
WMSN	-	Wireless Multimedia Sensor Network
WPAN	-	Wireless Personal Area Network
WSN	-	Wireless Sensor Network
ZMAC	-	Zebra MAC

LIST OF SYMBOLS

$\lambda_1,\lambda_2,\lambda_3$	-	optimal weight value
P_r	-	received power
P_t	-	transmitted power
d	-	distance
G_t	-	transmitter antenna gain
G_r	-	receiver antenna gains
L	-	system loss factor
λ		wavelength
d_o	-	reference distance
β	-	path loss exponent
X_σ	-	Gaussian random variable
σ_{dB}	-	standard deviation
$Vbatt$	-	battery voltage
$Vmbatt$	-	maximum battery voltage
V_{ref}	-	voltage reference
delay (S/N)	-	total delay of one hop neighbour
D(S/N)	-	one hop distance between two nodes
V	-	velocity
Vm	-	the maximum velocity of rf signal
$P_L(d)_{dB}$	-	path loss model
$P_L(d_o)_{dB}$	-	path loss model at reference distance
$f(x)$	-	fairness index
xi	-	nodes that has data
k	-	number of bits per pixel
Y_D	-	reconstructed video
Y_S	-	original raw video

N_{row}	-	at each row
N_{col}	-	at each coloum
$Rt_i - St_i$	-	delay between receiver and sender for packet i
N	-	total number of packet
N_i	-	sink node
N_0	-	source node
G	-	undirected graph
E	-	set of links connecting two adjacent nodes
N_s	-	set of nodes
tT_1 , tT_2	-	time token transmission
TSToken	-	recorded time when the token packet is transmitted
TRTack	-	recorded time when the node receives the tack
L_{token}	-	token packet size
Rb	-	link data rate
ds	-	distance between hop

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CHAPTER 1

INTRODUCTION

1.1 Background

The rapid advancement in protocol design for Wireless Sensor Network (WSN) is due to the higher demand to wirelessly connecting devices with low power consumption to link inaccessible area and hazardous environments such as in high-security place and high radiation area. WSN is defined as a network that consists of a large number of sensor nodes and a base station which communicate among themselves via radio signals [1] as illustrated in Figure 1.1. A sensor node has the capability to sense the physical environment depending on the type of transducers that attached to it such as temperature, humidity, voice, image or video [2][3] and also acts as a router in ad hoc WSN network. A base station is referred as a sink node or destination node that collects the entire information sent by the sensor node.

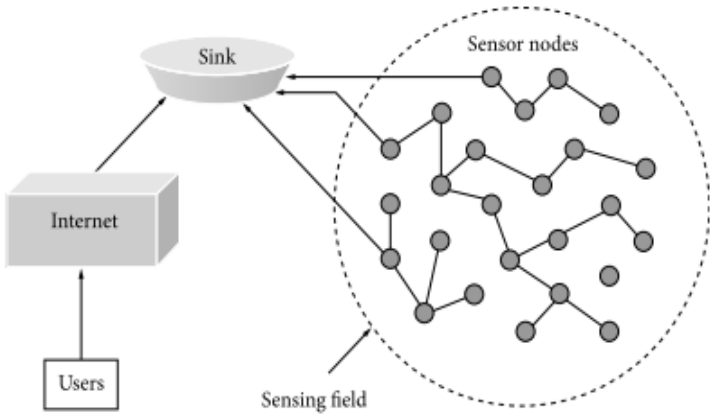

Figure 1.1 Structure of wireless sensor network

Since 2003, the Institute of Electrical and Electronics Engineers Standards Association (IEEE-SA) has released the new standard associated with WSN which is IEEE 802.15.4 that is specifically design for low rate wireless personal area network (LR-WPAN)[4] and also for short range communication with low power sensor networks. This enables the IEEE 802.15.4 to be used widely in most applications such as environmental monitoring, target detection, industrial process monitoring and emergency measures. Moreover, this standard has shown a good performance for low data traffic application as studied in [5],[6] and [7].

Albeit the good performance benchmark by the standard, the extension to higher traffic application imposes new challenges and opportunity to support the additional services. The high traffic applications in WSN involve the transmission of multimedia application such as image, audio or video and it is known as Wireless Multimedia Sensor Networks (WMSN). Most of the previous works on WMSN applications over IEEE 802.15.4 focus on image transmission [8][9], and very limited on the video applications. Hence, it imposes that video transmission is a challenging aspect of WSN related research due to the large amount of data generated by sensor nodes.

In general, wireless standard such as IEEE 802.11, IEEE 802.15.3 and Bluetooth are used for video applications since they offer much higher data rates [10]. It is noted that the manufacturing cost and power for video transmission will be lowered if IEEE 802.15.4 based devices are used. This standard can be considered as a promising means to establish green telecommunication networks. It is a worldwide goal to minimize energy consumption of any design in the telecommunication sector and the importance of the energy efficiency in telecommunication industry are discussed in [11].

Due to its minimal power consumption, the earlier standard is more suitable for low power sensor networks when compared to IEEE 802.11 based network because the latter possess high energy overhead [12]. Due to low data rate communication supported by IEEE 802.15.4, a video codec standardized by the

Moving Picture Expert Group version 4 (MPEG-4) for low bit rate digital media applications will be used because of its optimal compression technique [13] [14].

However, the transmission of video application in WSN is known to be very sensitive to packet loss in the medium. Hence, the design of Medium Access Control (MAC) protocol has to be reliable, error free data transfer with minimum retransmissions while supporting application specific Quality of Service (QoS) requirements [15]. This is due to the following: (1) MAC layer is responsible to control channel access that allows communication between multiple nodes within a network, and (2) the MAC layer has significant importance in wireless networks as it organizes how the channel is shared across the users, which directly impacts the system throughput, fairness, reliability and QoS performance metrics.

Recently, hybrid MAC protocols that combine the contention and reservation protocols have appeared in many wireless research designs, especially for real-time communication in WSN [16]. This is due to its capability to provide a mechanism that can guarantee support for real-time traffic, while promoting energy efficiency and scalability [17]. One of the reservation protocols that can provide higher reliability with no synchronization issue is a token protocol. The token protocol is still new in wireless network but this protocol already applied in wired network with good network performance.

Nowadays, one of the popular method to increase the flexibility of the protocol design that proposed by many researchers is a cross layer design strategy [18][19]. Particularly, the combined approaches that jointly consider MAC and routing also have been studied extensively and have shown positive outcome [20].

1.2 Problem Statement

Due to low data rate supported by IEEE 802.15.4 and the characteristic possessed by wireless networks (for instance, invariance channel condition), the high

traffic data which is multimedia application specifically video transmission over WSN imposes new research issues and challenges. Based on the IEEE 802.15.4 related literature, most of the previous works on multimedia applications focuses on image transmission. However, very limited works have been found with regards to video transmission.

In video application, the transmission of several packets may be impaired with added noise at the end of the receiver side. This happens due to packet loss and corruption of some of the important frames during the transmission due to noise and interference on the wireless channel. Moreover, as multiple users transmit data at the same time, packet collision occurs especially via wireless medium. The channel access controlled in a wireless network is managed by the MAC layer protocol. The MAC layer protocol has responsibility to ensure the channel is free before any transmission occurs to reduce packet collision and achieve energy efficiency. In order to achieve good quality of video application, the MAC protocol has to be reliably designed.

The widely used MAC protocol found in wireless related research is a contention protocol which is Carrier Sense Multiple Access (CSMA). This is due to its high performance in scalability. However, it suffers from collision problems.This is due to the reason that, those packets collide before reaching the destination/sink node that consequently result in errors or incomplete messages to the receiver. Furthermore, higher number of collision could possibly reduce the overall network throughput. The retransmission of those packets will increase the end-to-end delay and energy consumption in the network. Even though, there is some of MAC protocol that enhances the traditional CSMA protocol by adjusting the backoff value, the collision problem still occurs. Hence, to overcome a collision problem in CSMA protocol, a reservation protocol which is Time Division Multiple Access (TDMA) is widely used [21]. However, TDMA faces the difficulty to maintain with dynamic topology changes and strict synchronization problem.

Thus, hybrid MAC design has been applied to improve network performance with a combination of both protocols. Moreover, based on network performance, the

CSMA protocol exhibits better performance under light loaded, meanwhile TDMA has better performance in high traffic load [22]. However, the hybrid MAC that applied traditional TDMA experiences strict synchronization. Usually for time synchronization, centralized approach is used to ensure nodes in the network have the same clock[1]. Managing inter-cluster communication and interference is a challenging task [23]. For small topology network (for example single hop network), clock drift may be small and relatively does not have an impact on network performance. However, for large topology networks with multi-hop communication, it is difficult to ensure the entire nodes are having the same clock (synchronized). Some of TDMA MAC design assumption has stated perfect synchronization in their protocols or used global positioning system for synchronization [24][25][26]. However, the synchronization is a challenging task in multi-hop network especially in hardware development. To assume the synchronization is perfect is impractical.

Another issue in designing MAC layer protocol is to manage the usage of limited energy as energy is one of the most important attributes in sensor networks. The retransmission of packet collided should be avoided and transmission of the beacon packet at the beginning of the time slot to achieve the perfect synchronization in the TDMA protocol should be minimized because it consumes a lot of energy [27].

Hence, to overcome these problems, unsynchronized TDMA which is token approach protocol is proposed in this work. To the best of our knowledge, none of the existing research on WSN has combined CSMA and token protocol approach in video transmission. Besides, to overcome the long delay, the cross layer design strategy between MAC and routing protocol are also included as part of this work.

[1]Clock here means timer setting in sensor node

1.3 Research Objectives

The main objective of this research is to develop a reliable MAC layer protocol for high traffic data and video transmission over IEEE 802.15.4 standard. The proposed work must achieve good network performance (high throughput and energy efficiency) and must satisfy the QoS demand for streaming video application. The QoS demands are evaluated in terms of packet delivery ratio, Peak Signal to Noise Ratio (PSNR), energy consumption and end-to-end delay. The specific objectives in this work are as follows:

- To develop a reliable MAC layer with token approach protocol for wireless single hop network and implement a cross layer design strategy in the proposed MAC protocol
- To develop a reliable hybrid MAC layer with combination of CSMA and token approach protocol for wireless multi-hop network and implement a cross layer design strategy in the proposed hybrid MAC protocol
- To enhance the hybrid MAC layer protocol to support video application and analyse suitable environment for video application in IEEE 802.15.4 network.

1.4 Scope of Work

This research focuses on the designing of the MAC layer protocol that is highly subjected to minimize the number of collision for high traffic application. In this work, the hybrid MAC is proposed with the combination of cross layer design strategy between MAC and routing protocol and between MAC and application layer. The Real-Time with Load Distribution (RTLD) routing protocol is adapted as a routing protocol.

The physical layer characteristic is based on IEEE 802.15.4 standard. This standard provides low data rate which is 250kbps with maximum transfer unit (MTU) size of 127kbyte. The network is set up with star topology for single hop

network and grid topology for multi-hop network to ensure that the coverage area between each node is the same.

In this research, the proposed protocol is developed and verified using Network Simulator (NS2). The cygwin window is used to encode the video into trace file. To verify the proposed protocol, two types of traffic that considered in the simulation are scalar data and video data. First, the scalar data are varied from low traffic, which is 10packets/second to high traffic, which is 100packets/second in order to observe the effect of high traffic application in proposed MAC. The 100packets/second is classified as a high traffic because in idle condition where there is no link quality problem occurs, the IEEE 802.15.4 can support 246packets/second [28]. The idle condition is not happen in real scenario due to shadowing effect. Then, for video data, the MPEG-4 video traffic is used and the simulation is done for low, medium and high motion video. For video application, only one source node is used to generate the video. This is due to the reason that IEEE 802.15.4 medium provides low data rate (limited bandwidth). To validate the proposed MAC protocol for video transmission, the results from the simulation are compared with the results from related testbed experiment analysis.

1.5 Research Contributions

The proposed Hybrid MAC protocol is designed to support high traffic application such as video transmission in wireless network. Besides, the proposed MAC is to ensure the reliability of high traffic application and the QoS of video transmission in multi-hop WSN are achieved. The major contributions of the research work are as follows:

- **Development of token protocol in MAC layer design for wireless network**

The token protocol is widely used in wired network such as in ring or bus topology to increase the throughput and provide fair channel access in the network. In wireless network, the proposed token protocol is design to provide secure channel access and not bounded with strict time synchronization problem. The token recovery mechanism, token generation mechanism and token passing mechanism are proposed in token management to ensure good network performance in term of high throughput, minimize the collision, reduce end-to-end delay and achieve energy efficiency.

- **Cross layer design between MAC and routing protocol**

The decision of token passing in the network is based on cross layer design strategies between MAC and routing protocol. The routing protocol chooses the next hop node based on the physical layer parameter such as link quality, packet velocity and remaining power. MAC layer takes advantages of the decision in routing protocol to pass the token to the next hop node in the network. Through this cross layer design strategy, the resource is fully utilized because the token is only passed to the node that has the data to transmit. As a result, the data can be forwarded faster to the destination/sink node and the end-to-end delay will be decreased.

- **Selection of values in video encoder parameters based on exhaustive search**

The video application produces large amounts of data in the network. This contributes to the buffer overflow (high packet drop) and long delay queue. The appropriate values of video encoder parameters should be selected to reduce the size of video application. In this work, the MPEG-4 codec[2] is used to compress the video. There are two threshold parameters that have been set which are bit rate requirement and PSNR value for acceptable video quality. The video encoder parameters such as

[2] codec is term for encoder and decoder for video compression technique

group of picture, frame per second and quantization scale are varied using exhaustive search to meet the threshold value. This contributes to the video compression based on the bit rate that supported by selected wireless standard and at the same time maintain the video quality. As a result, the number of generated packet is reduced and the number of packet dropped at the buffer is minimized, particularly for the packet that carries the important frame. In addition, it can reduce the long delay experience by the buffer because of the long queue.

- **Support video application in low data rate network**

Usually, the platform for video application is using high data rate network such as IEEE 802.15.3 and required high power consuming. However, the ability to send the video application in low data rate network such as in IEEE 802.15.4 contributes to the low cost budget and gives advantage towards green technology environment due to low power consumption.

1.6 Significance of Research

The proposed MAC protocol can provide reliable and robust data transmission. The reliable data transmission is needed in many types of application such as video, audio transmission and critical data application because of its competency to minimize packet collision. In addition, the proposed MAC achieves high energy efficiency and can prolong the battery lifetime of the wireless sensor node due to low power consumption. Moreover, it can be applied in any MAC protocol in wireless network such as IEEE 802.14.5, IEEE 802.11 and IEEE 802.15.3. In addition, the proposed MAC can be adapted to both single hop and multi-hop network.

The potential applications of the proposed MAC protocol include video application and critical data application. In video application, a sensor node can be placed in the house to monitor the behavior of a hired babysitter towards the children

without the person being aware of being monitored due to the small size of wireless sensor node. For critical data application such as volcanic monitoring where the data that are transmitted is very important to detect unusual behavior of the volcano activity. This kind of natural risk is unavoidable, but frequent monitoring and earlier warning can help the authorities to evacuate the citizen from dangerous area. Hence, the human and material losses due to the catastrophe can be minimized.

1.7 Thesis Organization

The thesis highlights the development of token approach protocol in hybrid MAC layer design for high traffic data which is video application. This thesis consists of six chapters that cover the main contributions of this research. Chapter 1 elaborates the background, problem statement, objectives, scope, contributions and significance of the research.

Chapter 2 presents the literature review that drives the proposed protocol in this research work. It begins with the overview of WSN technology and the architecture layer protocol. Then, IEEE 802.15.4 standard specification is described for both physical and MAC layer. To make a better understanding of video application, this chapter also explains the video coding standard that consists of the MPEG-4 video encoder and video application requirement as well as the research challenges of multimedia application in WSN environment. The related research in latest existing MAC, hybrid and token protocol are also discussed and analysed. In addition, the routing protocol, propagation model and network performance metric that are used in this research work is highlighted. At the end of this chapter, several loopholes are identified which become the driver for this research work.

Chapter 3 explains the overview of design framework and research methodology of the proposed MAC protocol for both single and multi-hop network. MAC layer with token approach (MAC-TA) protocol is designed for single hop network and hybrid MAC with token approach (HMAC-TA) protocol is designed for

multi-hop network. Then, enhanced HMAC-TA (eHMAC-TA) protocol is proposed for video application in WSN. The proposed MAC protocols are highlighted using flowchart, block diagram and state machine diagram for better understanding. This chapter also covers the network model and simulation tools that are used in analyzing the performance of the proposed MAC protocol.

Chapter 4 presents the detail algorithm for MAC-TA and HMAC-TA protocol. The cross layer design strategy proposed in both protocols is explained in this chapter. The token protocol management that includes token passing, token recovery and token generation mechanism are explained. Then, to evaluate the proposed MAC protocol, analysis of high traffic load of scalar data transmission is presented. The performance analysis of MAC-TA and HMAC-TA is evaluated in comparison with CSMA protocol.

Chapter 5 highlights the enhancement of HMAC-TA protocol namely eHMAC-TA protocol that is specifically designed for MPEG-4 video transmission over WSN. The token management including token generation, token passing and token recovery mechanism is improved for video application, and is also described in this chapter. Lastly, the simulation study and network performance analysis of eHMAC-TA protocol for video transmission in WSN is evaluated and compared with the HMAC-TA, CSMA and latest related research work from the literature.

Finally, Chapter 6 concludes the significant improvement of the research work, along with recommendations for future work.

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