Service Differentiated QOS Guaranteed Cross Layer Solution for Underwater Acoustic Sensor Networks (SD-QCLS)

Vidyalakshmi K, **M.Siddappa, B.Shanmukha**

Abstract: Physical characteristics limits the capability of sensor network in case of underwater deployment. Factors like medium delay, doppler spreads and limited bandwidth are challengers to achieve a QoS (Quality of Service) guarantee in under water acoustic sensor networks. Under these conditions maximizing the bandwidth availability with consideration for application traffic requirements is important. This work proposes a service differentiated QOS guaranteed cross layer solution to maximize the available bandwidth and life time of the network under the constraints of application traffic requirements. At all different layers of IEEE 802.15.4 protocol stack, i.e., Application Layer, Session Layer, Network Layer, MAC Layer, and PHY Layer, the solution uses network parametes to optimize available bandwidth and also QoS. The solution involves redundancy and prediction based content coding at application layer, QoS based rate control at session layer, load based routing, transmission range adjustment at physical layer for guaranteed QoS delivery over acoustic sensor network.

Keywords* : *Error Control Code, Link quality, Residual energy, Route Desirability Factor.

I. INTRODUCTION

The applications with respect to UASN (Underwater Acoustic Sensor Network) in different application areas like marine life monitoring, oil line monitoring etc has increased the research focus on optimal designing UASN. Different from traditional sensor networks, acoustic signal is used for communication in UASN which has five times lesser propagation speed compared to radio signals. Due to this, the data rate is low and it hardly exceeds 40 kb/s at a1km range. Underwater sensors oscillates due to water current which causes variance in data rate and delay. Senor nodes do fail with higher probability in case of UASN due to the oceanic salt water environment and damage due to marine life. Maintaining a guaranteed QoS under different service level application requirements necessitates a optimized use of available bandwidth and delay characteristics of the UASN.

Revised Manuscript Received on November 15, 2019

Vidyalakshmi K Research Scholar Dept. of Computer Science & Engineering VTU-RRC, Belagavi-590018 Karnataka, India

Dr.B.Shanmukha Professor & Head Dept. of Computer Science & Engineering Sri Siddhartha Institute of Technology

Tumakuru-572105 Karnataka, India

Dr.M.Siddappa Associate Professor Dept. of Mathematics PES College of Engineering Mandya-571401 Karnataka, India

We propose a Service differentiated QoS guaranteed Cross Layer Solution (SD-QCLS) for under water acoustic sensor networks. This approach ensures the selection of efficient QoS delivery over UASN.

It is accomplished by exploiting the features of cross-layer architecture of IEEE 802.15.4 protocol stack with usage of transmission power control, error coding, selective multipath propagation, network topology and adaptive routing. Further the protocol differentiates the application layer services and adjusts data rates for different applications dynamically based on current network characteristics. The proposed SD-QCLS is implemented in NS2 and tested for UASN conditions. Through simulation measurements, QoS is found to be far better in proposed solution compared to the existing works.

II. RELATED WORK

The survey is conducted in two categories of energy efficiency and cross layer solutions.

A. Energy Efficiency

Energy Routing as well as Link quality with respect to IoT (Internet of Things) was shown in [2]. This work proposed an end to end link quality estimator mechanism and used it with residual energy and hop count for the purpose of route selection. Furthermore the work proposed an event driven mechanism with respect to load balancing which avoided energy depletion of nodes. The link quality estimator mechanism is heavily dependent on network topology. They also proposed Distance, Energy and Link quality based Routing protocol (DELR) for IoT to improve the packet success ratio. Link quality is calculated in terms of RSSI (Radio Signal Strength Indicator) and the AODV (Ad hoc On-demand Distance Vector) routing protocol messages is added with the estimated link quality indicator value. Based on threshold poor quality links are filtered in the routing. Authors in [3] proposed an EEPR (Energy-Efficient Probabilistic Routing) algorithm. The work applies energy efficient probabilistic control on RREQ (Route REQuest) that made use of each node's residual energy as well as ETX (Expected Transmission Count) metric of AODV protocol. The solution is able to improve the network lifetime of AODV protocol.The solution considers only reduction in routing overhead but does not consider energy efficiency in data forwarding phase.
Grasielli et al. [4]

addressed energy efficient communication problem using the parameters of optimized channel coding. A two-layer encoding scheme was considered thus including FEC (Forward Error Correction) codes as well as FC (Fountain Codes) to the UAN scenarios without considering the feedback channels. De Souza et al [5] investigated minimum energy that was consumed by the transmission of one bit information across underwater acoustic channel. Taking into consideration the usage of binary FSK (Frequency Shift Keying) modulation as well as convolutional error correcting codes, they clearly have optimized, operation frequency, code rate and also the SNR (Signal-to-Noise Ratio) when the target FER (Frame Error Rate) was to be achieved. Thus their research output showed that making the correct choice of thecode rate will always make a high impact on overall consumption of energy and henceforth, lifetime of devices of underwater communication. Inclusively it also increases transmission range. De Souza et all [6] analyzed the amount of energy that is being required for successfull transnmission of data bits across multi-hop underwater acoustic network by considering optimum number of hops, retransmissions, code rate as well as SNR. Collectively they have investigated delay constraints impact on total energy consumption which allows retransmission limited or unlimited. Higher ended energy savings is obtained when all these parameters are totally optimized for given any link distance. Though impact of multiple hops is quite beneficial, it allows retransmissions that leads to energy savings. Simao et all [7] analyzed consumption of energy of the underwater network that includes FC, which can transmit infinite amount of coded bits that ensures given target FER at receiver without retransmissions. Additionally they have optimized carrier frequency, SNR as well as code rate for such target FER. Analysis have proved that the use of FC reduces energy consumption almost by 30%. Fatma et all [8] made a deep analysis on impact of all these different characteristics of underwater balancing the energy consumption with respect to underwater sensors. Thus a balanced strategy for routing that included deployment pattern was proposed that determined load weight for all possible next hop, which lead to equitable energy consumption for all underwater sensors and due to which, energy holes problem was solved thus improving the network lifetime. An EULC (Energy-balanced Unequal Layering Clustering) algorithm was given by Rui Hou et all [9], which improved energy efficiency of acoustic sensors. This algorithm designed unequal layering which was based on depth of the node, thus providing solution to hot spot, issue by constructing clusters of different sizes within same layer. Through simulation author proved that energy is balanced in UASN nodes and life time is prolonged.Tayyaba Liaqat et all [10] gave DB-EBH, a Depth-Based Energy-Balanced Hybrid routing protocol for UWSNs (UnderWater Sensor Network) which was the hybrid approach based on directas well as multi hop communication and it also considers node’s linear random deployment which selects a priority node which is its neighbor for forwarding data on depth basis from sink. A FAF-EBRM (Forward-Aware Factor-Energy Balanced Routing Method) was proposed by Degan et all [11]. In this, next-hop node is being selected with respect to awareness of forward energy density and link weight. Hence additionally reconstruction mechanism is designed for the local topology.The experimental results showed that FAF-EBRM has outperformed LEACH (Low Energy Adaptive Clustering Hierarchy) and EEUC (Energy Efficient Unequql Clustering), that balanced energy consumption which prolonged the function of lifetime and guaranted very high QoS.

For acoustic 3D UWSNs an EECPPA (Energy Efficient logical Cubical layered Path Planning Algorithm) and MSEECPPA (Multiple Sink EECPPA) was proposed by M. Aslam et al [12] . These algorithms were completely distributed and was highly adoptive in executing logical divided 3D networks into the multiple cubes. During the variations in the location of sensors, these models were quite flexible and had higher ability to reconfigure logical cubes size within 3D cubical UWSNs and these cubes played major role in selecting Cluster Heads (CHs) i.e a multiple group of leading nodes. The executional and iterative operations of these algorithms were classified as; Network Dimensional Phase (NDP), Network Settling Phase (NSP) and Network Transmission Phase (NTP). In NDP, multiple cubical layers were constructed, in NSP leading nodes were selected nearer to the reference point of cube's boundaries and in NTP the actual communications of nodes takes place. MSEECPPA algorithm selects multiple sinks, to make the utilization of multi-hoping mechanism which increases lifetime of nodes which are far from Base Station (BS).

B. Cross Layer Solutions

Based on wireless adhoc networks a cross layer transmission model for IoT was proposed by author [1]. In physical layer it applied a decentralized coded caching and at media access control layer a content division multiplexing. For a specific traffic model of alternating high and low traffic periods, the solution worked better. The solution given also had reduced network congestion as well as delay, but energy consumption was not desirably considered. A cross-layer MAC protocol was proposed by Xueyuan Su et al. [13] which at the network layer interacted with a price-based rate allocation scheme. For clique constraint of wireless medium, a clique based price was generalized for congestion signal, that controlled end-to-end rates of multi hop flows. Later on MAC protocol will schedule transmission of contention free packets of single-hop sub flows.TDMA (Time Division Multiple Access) based underwater acoustic channel access technique was analysed and proposed by Chao Lv et all [14], which improved utilization of channel. In UA-MAC (Underwater Acoustics-Media Access Control), the time slot given for each node accessing acoustic channel was being assigned with respect to pre-verified template, that goals in minimizing amount of slots decreasing end-to-end delay. Additionally a protocol based on piggyback was implemented which synchronized and scheduled the network. Hao Wang et all [15] proposed a novel cross-layer routing protocol which was established on network coding for UWSNs, that utilizes network coding as well as cross-layer design to forward data packets greedily and efficiently to the sink nodes.

This protocol takes full advantage of multicast transmission and later on decodes all the packets with encoded packets that is received from multiple potential nodes in the network. To expand and increase life cycle of network the transmission power is being optimized. Roberto Petroccia et all [16] represents a self-adaptive and fully distributed, cross-layer routing protocol for UASN which indeed supports multiple coded modulation schemes and crosslayer information usage that can interact with the physical layer. Along with topological data and energy link quality, information is being exploited thus selecting relay node. Guangjie Han et all [17] proposed a cross layer solution combining VBF (Vector Based Forwarding) routing algorithm with consideration of number of times the data is retransmitted as well as residual energy that helps in making a optimized decision whether the node has to forward the data or not.

From the survey, it can be observed that there is no single solution addressing the multi service based QoS guarantee with effective bandwidth utilization, energy of the nodes and delay characteristics of UWSN. Designing a cross layer solution with optimization of QoS under constraints of available bandwidth and delay characteristics was a challenge.

III. PROPOSED SOLUTION

The architecture of the proposed solution is shown below in Fig. 1.

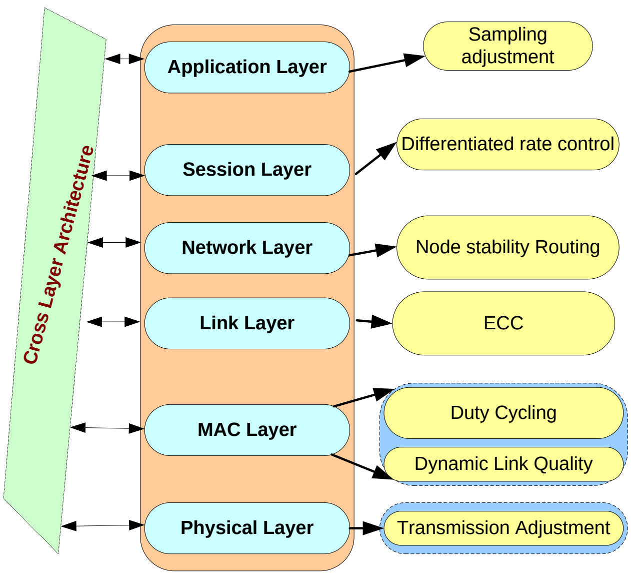

Fig. 1. Architecture of SD-QCLS

The proposed service differentiated QoS guaranteed cross layer solution (SD-QCLS) involves solutions at Physical, MAC, Link, Network, Session and Application layers to achieve following objectives

1. Increasing the packet delivery ratio
2. Reduced delay for the high priority packets compared to that of low priority packets
3. Reduce the energy consumption

A. Application Layer

The sampling rate of the sensor is controlled thereby a control is done on the outgoing packet flow from the nodes as shown below in Fig. 2. The sampling rate is controlled based on two parameters i.e the latency in routing path and residual energy of nodes. Latency is modeled in terms of Round Trip Time (RTT/2). The RTT is modeled as probability mass function of delay distribution as shown below in (1).

$$RTT = \begin{cases} \sum_{i=0}^{\infty} f_i(a).f_i(b) \ , x = 0 \\ \sum_{i=0}^{\infty} f_i(a).f_{2x+i}(b) + \sum_{i=0}^{\infty} f_i(b).f_{2x+i}(a), x > 0 \end{cases} \quad (1)$$

Where a, b are forward and backward directions from transmitter to receiver and f(z) is the probability mass function of delay of direction z.

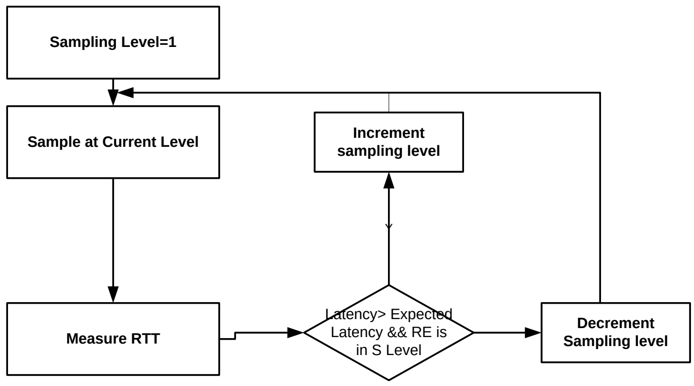

Fig. 2. Sampling Control

B. Session Layer

The application services packets are categorized to real and non real time flows before passing to the session layer. At each of the hops flow control is done on the packets based on the type of the service flow. Each relay node estimates the traffic demand for relaying the packets from its neighbor nodes and allocates the timeslots proportional to the traffic demand and priority of the packets from the nodes. This process is repeated at beginning of each time frame. The Future traffic Demand (FD) for a neighbor node is estimated as shown below in (2).

$$FD = \min(MA_i + D_i, T \times \Delta) \quad (2)$$

Where MA is the exponential moving average of incoming traffic to node, D is the traffic amount in the buffer and T is the current physical transmission rate. MA is calculated as shown below in (3).

$$MA_i = \begin{cases} \alpha.T + (1-\alpha)MA_{i-1} \ if \ T \neq 0 \\ (1-\alpha)MA_{i-1}, otherwise \end{cases} \quad (3)$$

Traffic demand is calculated for each neighboring node that sends packets and slots ns for node x is allocated from total of N as shown in (4)

$$ns_x = \frac{FD_x}{\sum_{x=1}^{n} FD_x} * \frac{P_x}{\sum_{x=1}^{n} P_x} \quad (4)$$

Where P is the priority of packet from node x. Based on packet priority information from the application layer and estimated traffic demand, the slots are allocated dynamically for the real and non real time flows for processing of the packets.

C. Network Layer

QoS-Energy balanced routing is proposed at network layer and its a reactive routing protocol built on top of AODV. Among each of the routes constructed by AODV, RDF (Route Desirability Factor) is calculated and the routing path with highest RDF is selected for routing. RDF is calculated as shown in (5).

$$RDF = \alpha \times DF + (1 - \alpha) \times RF \qquad (5)$$

Where DF is the Delay Factor and RF is the Residual energy Factor. DF is calculated as shown in (6).

$$DF = \sum_{i=1}^{n} \{(np_i + 1).\left(\frac{1}{1-P_i}\right).pt_i\} \qquad (6)$$

Where np_i stands for number of packets in the queue at link i , P_i stands for transmission failure probability at link i and pt_i is packet transmission time over link i. The packet transmission time over link can be modeled in terms of influence on maximum throughput as shown in (7).

$$pt_i = \frac{L}{(1-RF)B_i} \qquad (7)$$

Where B_i is the channel bandwidth for link i under the influence of interference and L is the packet size. Net bandwidth usage was expressed as $(1 - RF)$ and thus RF is calculated as shown below in (8).

$$RF = \frac{\min(re_i, re_j)}{IE} \qquad (8)$$

Where re_i is the residual energy at link i. AODV routing protocol is modified to incorporate DF. Every time RREP is forwarded, each node calculates it parts of DF and adds the new field DF into RREP (Route REPly) message. The source node which originate the RREQ message, selects the best RREP route with highest values of DF and use it for forwarding the packets. The RREQ forwarding length at each hop is controlled by configuring a minimum value, so as to reduce control of area of forwarding of RREQ, which reduces the number of messages in network, which inturn further reduces the energy consumption.

D. Link Layer

At link layer use of ECC (Error Control Code) is proposed to solve the problem of retransmission and energy wastage due to retransmission. Each Level 2 sensor node sends the event sensed to the Level 2 cluster head node using DPSK (Differential Phase Shift Keying) modulation. The data from Level 2 sensor node to Level 2 cluster head is sent with ECC that restores data in case of errors at cluster head without a need for retransmission. The use of ECC over noisy channel would provide the better BER (Bit Error Rate) performance for lower or same SNR when compared to that of an uncoded system as shown below in Fig. 3. RS (Reed Solomon) code is considered as best choice which has maximum energy efficiency in proper channel conditions.

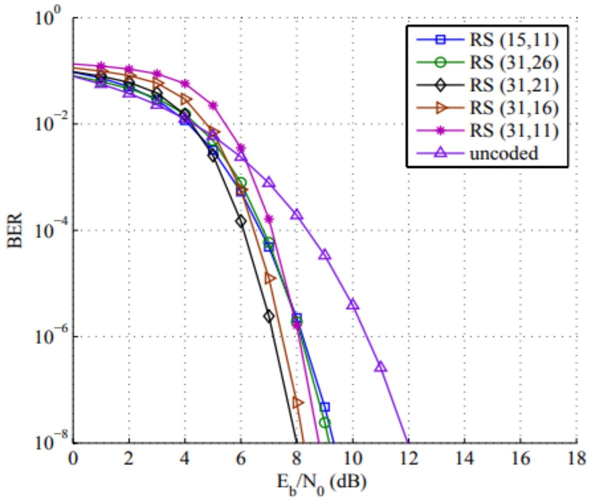

Fig. 3. BER vs SNR

The consumption of energy at the node, due to RS(n,k) is given as shown below in (9).

$$E = E_{RS}(q^2 - 1)log_2(q^2)|mE_T + (m-1)kE_R| \qquad (9)$$

Table-I gives the energy consumption is measured for different k,n values in RS.

Table- I: Energy Consumption vs RS code

RS code	Power consumption(nW)
RS(15,11)	200
RS(31,26)	125
RS(31,21)	150
RS(31,16)	275
RS(31,11)	450

From the results, RS (31, 26) gives satisfactory performance in terms of BER and has lower power consumption. So RS (31, 26) is used for error correction from sensor node to cluster head.

E. MAC Layer

Duty cycling and dynamic link quality based forwarding are two solutions adopted at MAC Layer. For the density based cluster created at Level 2, the level 2 nodes are allocated non conflicting duty cycle with cluster head node being a exception. Duty cycle time is allotted in proportion to the residual energy of node. But the traditional way of centralized duty cycle decision is not suitable for UWSN, since it involves frequent communication. We propose a distributed decision making by allowing each node to transmit along with probability which is based on residual energy of nodes as shown in (10).

$$\tau = \frac{1}{1-e^{-\gamma\frac{E_0}{E_i}}} \qquad (10)$$

Where E_0 is considered as initial energy of the node and E_i is considerd as node's current residual energy and γ is performance tuning parameter.

In this method transition probability decreases.

Dynamic Link Quality is parameter used for selecting sink by super cluster head among available multiple sinks. Each super cluster head node calculates link quality with respect to packet delivery ratio achieved over a period of time using Mean Exponentially Weighted Moving Average Algorithm as shown in (11).

$$\psi = \alpha * \psi + (1 - \alpha) * DR \quad (11)$$

Where α is in range of 0 to 1 and DR is the packet Delivery Ratio achieved is last interval. The cluster head calculates the link quality (ψ) for each as the energy level decreases, the reachable sink and selects the sink whose value is above a threshold.

F. Physical Layer

Transmission range adjustment is the solution adopted in physical layer for achieving energy efficient data forwarding. The transmission range is approximated as weighted function of residual energy and connectivity of the node as shown in (12)

$$T = w_1 \frac{1.25}{\sqrt{\rho}} + w_2 E_i \quad (12)$$

Where $w_1 + w_2 = 1$ and ρ is the density of node and this node density can be measured as number of unique hello broadcasts received at the node.

IV. RESULTS AND DISCUSSION

The proposed SD-QCLS solution was simulated in NS2. Simulation was conducted with following parameters as shown below in Table-II.

Table- II: Configuration Parameters

Parameters	Values
Number of Nodes	50 to 250
Communication range	100m
Area of simulation	1000m*1000m
Node distribution	Random distribution
Simulation time	30 minutes
Interface Queue Length	50
MAC	802.11
Number of Base station	1
Location of Base station	On surface
Initial energy of nodes	100 joules
Node movement	2-5 m oscillating around a center point

The proposed work is compared against [7] and [8]. Solution [7] implements code rate selection for efficiency in energy consumption, thus increasing network life time. Solution [8] is on optimizing number of hops under delay constraints to realize efficient QoS. Since both solution [7] and [8] address QoS and energy efficiency similar to the proposed work, they are used for comparison.

The performance is being measured with respect to

1. Packet Sucess ratio
2. Network overhead
3. Life time
4. Throughput
5. Delay

Packet delivery ratio is taken and is being measured for different number of nodes in all three solutions and plotted. Sensor nodes measures packet delivery ratio at level below d send packet at CBR(Constant Bit Rate) of 5 packets per seconds and the delivery ratio is measured at the sink. From the results, the packet delivery ratio is higher in present work compared to [7] and [8] as shown in Fig.4. The increment in packet success ratio is due to efficiency in path selection and data rate control at application and session layers.

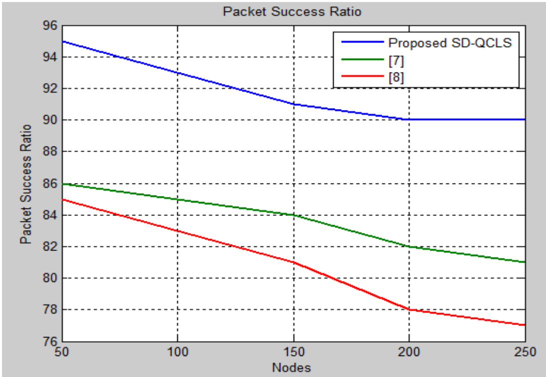

Fig. 4. Packet Succes Ratio

The network overhead is measured for different number of nodes in the network and is shown below in Fig.5, which is measured in terms of total number of bytes transferred to the network for a second and is seen to be comparatively lower in present work compared to [7] and [8]. The reduction in network overhead is due to restriction of forwarding length of RREQ in the proposed SD-QCLS.

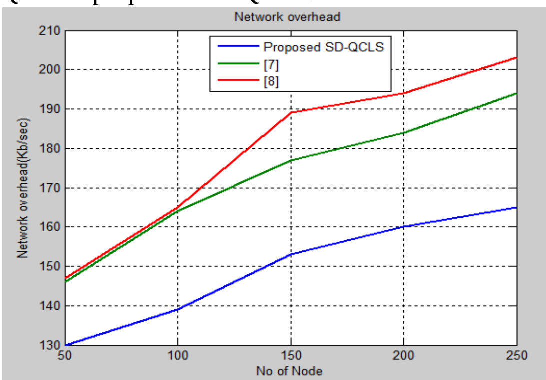

Fig. 5. Network Overhead

Life time is being measured as time when the first node energy reduces to zero and is measured for different size of network and is shown below in Fig.6. From the results, life time is higher in proposed solution compared to [7] and [8].

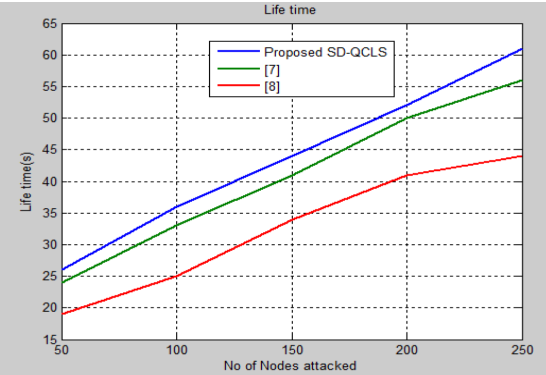

Fig. 6. Life time

The packet delivery ratio is measured for different speed of sensors as shown in Fig. 7. Its seen that packet delivery ratio is quite higher in the present work for different speed of nodes compared to [7] and [8]. Also at higher speeds the degradation in packet delivery ratio is lower in the proposed solution due to the transmission power adjustment.

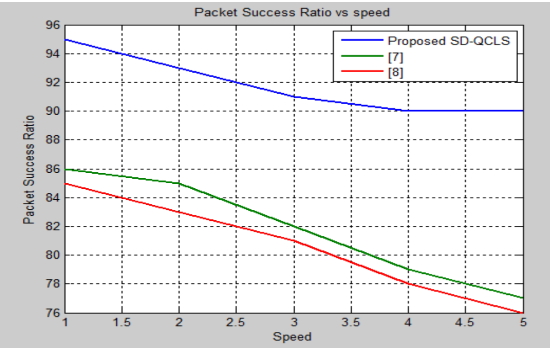

Fig. 7. Packet Delivery Ratio vs Speed

.

The network overhead is measured for different speed of sensors and is shown below in Fig.8 and density can be measured as the number of unique hello broadcasts received second. The network overhead increases as the speed increases, but the increase is lower in case of present work when compared to [1] and [4].

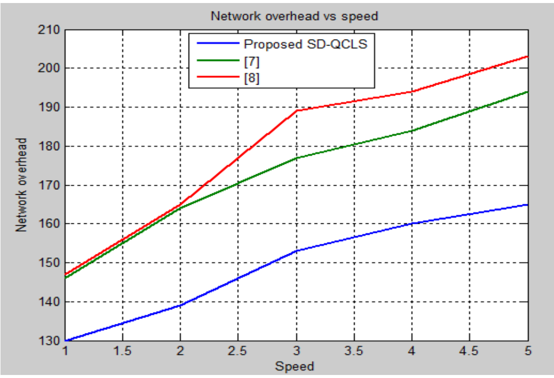

Fig. 8. Overhead vs Speed

The throughput at sink is measured for different number of nodes and result is given below in Fig. 9. Throughput is higher in the proposed SD-QCLS due to effective path selection based on delay and nodes residual energy.

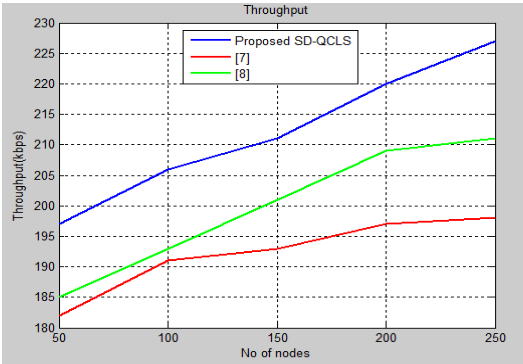

Fig. 9. Throughput vs Nodes

The delay for higher priority packets is measured with respect to different number of nodes and is shown below in Fig. 10. The delay is less in the proposed solution due to service differentiation based flow control at the session layer.

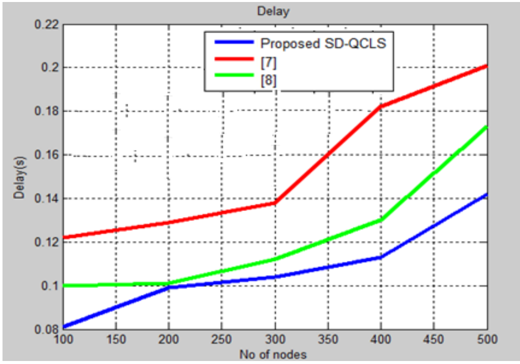

Fig. 10. Delay vs Nodes

V. CONCLUSION

In this work, a service differentiated QoS guaranteed cross layer solution (SD-QCLS) involving solutions at Physical, MAC, Link, Network, Session and Application Layers is proposed to ensure QoS and efficient energy consumption. The proposed work performs better than existing work with respect to packet delivery ratio, life time, throughput as well as network overhead. As network coding and error corrections are used, retransmissions are avoided in the network. Due to efficient selection of path that was based on delay as well as residual energy and data control at session and application layers, the QoS is improved. Service differentiation enables lower delay for higher priority packets. Duty cycling and transmission power adjustment resulted in less energy consumption and has increased the life time.

REFERENCES

1. X. Yang , L. Wang , J. Xie, Z. Zhang, “Cross-layer model design in wireless ad hoc networks for the Internet of Things,” *PLoS ONE*, vol. 13, 2018, pp. 1-10.
2. K.Machado, D.Rosário, E. Cerqueira, “Routing Protocol Based on Energy and Link Quality for Internet of Things Applications”, *Sensors (Basel)*, Vol. 13, 2013, pp. 1942-64.
3. S.H.Park, S.Cho, J.R.Lee, “Energy-Efficient Probabilistic Routing Algorithm for Internet of Things,” *J. of Applied Mathematics*, vol. 14, 2014, pp. 1-7.

4. G. Barreto, D.H.Simão, R.D.Souza, "Energy-Efficient Channel Coding Strategy for Underwater Acoustic Networks", *Sensors*, vol. 17, 2017, pp.7281-96 .
5. F. De Souza, R. Souza, G. Brante, M. Pellenz, F. Rosas, B. Chang, "Code rate optimization for energy efficient delay constrained underwater acoustic communications," *In Proc. of the OCEANS*, Genova-Italy, 2015, pp. 641-653.
6. F.De Souza,B. Chang, G.Brante, R. Souza, M. Pellenz, F. Rosas, "Optimizing the Number of Hops and Retransmissions for Energy Efficient Multi-Hop Underwater Acoustic Communications," *IEEE Sens. J.*, vol. 16, 2016, pp. 3927–3938.
7. D.H. Simao, B.S. Chang, G. Brante, R. Souza, F. De Souza, M.Pellenz, "Energy consumption analysis of underwater acoustic networks using fountain codes," *In Proc.of the MTS/IEEE OCEANS*, Monterey,CA, USA, 2016, pp. 1-4.
8. B. Fatma , Z. Chaima , B.Raouf, "Joint Routing and Energy Management in Under Water Acoustic Sensor Networks," *IEEE Trans. on Netw.and Service Management*, vol. 14, 2017, pp. 456-571.
9. H. Rui, H. Liuting, H. Shan, L.Jiangtao, "Energy-Balanced Unequal Layering Clustering in Underwater Sensor Networks," *IEEE Access*, vol. 6, 2018, pp.39685-39691.
10. L.Tayyabba, J.Nadeem, M.A.Syed, I.Muhammed, A.Mohammed, "Depth based energy balanced hybrid routing protocol for underwater WSNs," *Proc. of 18th IEEE Int. Conf. Netw.Based Inf. Syst*, Taiwan, 2015, pp. 20-25.
11. Z. Degan, L. Guang, Z. Ke, M. Xuechao, P. Zhao-Hua, "An Energy-Balanced Routing Method Based on Forward-Aware Factor for Wireless Sensor Networks," *IEEE Trans. on Industrial Informatics*, vol. 10, 2014, pp. 766-773.
12. M. Aslam, et al, "Energy efficient cubical layered path planning algorithm (EECPPA) for acoustic UWSNs,*" Proc. IEEE Pacific Rim Conf. Commun Comput.Signal Process*, Wah Cantt,2017, pp.1-6.
13. S. Xueyuan, C. Sammy, B.Masaki, "A Cross-Layer MAC Protocol for Underwater Acoustic Sensor Networks," *IEEE Sensors J.*, vol. 16, 2016, pp. 4083-4091.
14. L.Chao, W.Shuo, M. H. Tan, C. Lan, "UA-MAC: An Underwater Acoustic Channel Access Method for Dense Mobile Underwater Sensor Networks," *Int. J.l of Distributed Sensor Netw.*, vol. 10, 2014, pp. 1-10.
15. W.Hao, W. Shilian, B. Renfei, Z. Eryang, "A Novel Cross-Layer Routing Protocol Based on Network Coding for Underwater Sensor Networks," *Sensors(Basel)*, vol.17, 2017, pp. 1821.
16. P. Roberto, P. Konstantinos, A. Joào, F. Stefano, B.Stephane, P. Sean, "An Adaptive Cross layer Routing Protocol for Underwater AcousticNetworks,"*Fourth Underwater Communications and Networking Conference*, Italy, 2018, pp. 1-5.
17. H. Guangjie, S.Ning, W. Tongtong, J. Jinfang, S.Lei, "A Reliable and Energy Efficient VBF- improved Cross-layer Protocol for Underwater Acoustic Sensor Network," 11th EAI Int. Conf. on Heterogeneous Networking for Quality, Reliability, Security and Robustness, Taiwan, 2015, pp. 1113

AUTHORS PROFILE

Mrs.Vidyalakshmi K received B.E. degree in 2005 at Sri Siddhartha Institute of Technology, Tumakuru, Karnataka, India and M.Tech degree in 2011 at National Institute of Engineering, Mysuru, Karnataka, India. She is now the Research Scholar of VTU-RRC, Belagavi, Karnataka, India. She is working as Assistant Professor in the department of Computer Science and Engineering at BGS Institute of Technology, BG-Nagar, Mandya, Karnataka, India and has a teaching experience of 14 years. She has in her credit one research paper published in National Conference and one research paper published in International Conference (IEEE), which has received the best paper award. She also has published one research paper in reputed International Journal and the same has been published as a chapter in a book called HCMC.

Dr.M.Siddappa received his B.E. degree in 1989 from Mysore University Karnataka, India and M.Tech degree in 1993, from Mysore University, Karnataka, India. He received his Ph.D. degree in 2010 from Dr. MGR University, Tamilnadu, India. He is currently working as Professor and Head, Dept. of Computer Science and Engineering and aslo is the Dean Academics at Sri Siddhartha Institute of Technology, Tumakuru, Karnataka. His general research interests lie in the areas of Data structure and algorithm, Artificial Intelligence and Intelligent Systems, Computer Networking. His recent focus has been on underwater acoustic communications and networking. He has a teaching experience of about 26 years and has published more than 20 papers in reputed International Journals and has more than 20 conference publications in his credit. He has visited Louisiana State University, USA, California University, UC Berkeley, Sanfrancisco, USA and Wuhan University, Wuhan,China on research basis. He has a life membership for IJERIA, India, Indian Society for Technical Education, New Delhi, India and for Computer Society of India, India.

Dr.B.Shanmukha recevied his M.Sc degree in 1992 from Bangalore University, Karnataka, India, M.Phil degree 1994 from Bangalore University, Karnataka, India and Ph.D. degree in 2004 from Bangalore University, Karnataka, India. He is currently working as Associate Professor in the department of Mathematics at PES College of Engineering Mandya. His area of specialization is Graph Theory, and has special interest in networks and communication. He has a teaching experience of 26 years. He has in his credit more than 6 papers published in National and International conferences and more than 10 papers published in reputed International Journals. He has attend many Induction training programmes, seminars and workshops. He has a life membership of Indian Society for Technical Education, New Delhi, India, and for Ramanujam Mathematical Society, Tamilnadu, India