IEEE Access
Multidisciplinary ⁝ Rapid Review ⁝ Open Access Journal

Received May 11, 2019, accepted May 30, 2019, date of publication June 10, 2019, date of current version July 2, 2019.

Digital Object Identifier 10.1109/ACCESS.2019.2921833

Adaptive Energy Aware Quality of Service for Reliable Data Transfer in Under Water Acoustic Sensor Networks

REVATHI SUNDARASEKAR[1], P. MOHAMED SHAKEEL[2], S. BASKAR[3], SEIFEDINE KADRY[4], GEORGE MASTORAKIS[5], CONSTANDINOS X. MAVROMOUSTAKIS[6], R. DINESH JACKSON SAMUEL[7], AND VIVEKANANDA GN[8]

[1]Anna University, Chennai 600025, India
[2]Faculty of Information and Communication Technology, Universiti Teknikal Malaysia Melaka, Durian Tunggal 76100, Malaysia
[3]Department of Electronics and Communication Engineering, Karpagam Academy of Higher Education, Coimbatore 641021, India
[4]Department of Mathematics and Computer Science, Faculty of Science, Beirut Arab University, Beirut 11072809 , Lebanon
[5]Department of Business Administration, Technological Educational Institute of Crete, 72100 Heraklion, Greece
[6]Department of Computer Science, University of Nicosia, 24005 Nicosia, Cyprus
[7]School of Computing Science and Engineering, Vellore Institute of Technology University, Chennai 600127, India
[8]Department of Computer Science and Engineering, MITS, Madanapalle 517325, India

Corresponding authors: Revathi Sundarasekar (revathisundar161@outlook.com) and George Mastorakis (gmastorakis@staff.teicrete.gr)

This work was supported in part at the Ambient Assisted Living (AAL) Project vINCI: Clinically-Validated INtegrated Support for Assistive Care and Lifestyle Improvement: the Human Link through the Research Promotion Foundation (RPF) in Cyprus of the AAL Framework under Grant vINCI /P2P/AAL/0217/0016.

ABSTRACT Currently, reliable data transfer, and energy management have been considered as a significant research challenge in the underwater acoustic sensor networks (UWASN) owing to high packet loss, limited ratio of bandwidth with significant incur of energy, network life time with high propagation delay, less precision with high data hold time and so on. Energy saving and maintaining quality of service (QoS) is more important for UWASN owing to QoS application necessity and limited sensor nodes. To address this issue, several existing algorithms such as adaptive data forwarding algorithms, QoS-based congestion control algorithms and several methodologies were proposed with high throughput and less network lifetime as well as the less utilization of energy in UWASN by choosing sensor nodes data based on data transfer and link reliability. However, all the conventional algorithms have fixed data hold time, which incurs more end-to-end delay with less reliability of data and consumption of high energy due to high data transfer reachability. This high end research proposes adaptive energy aware quality of service (AEA-QoS) algorithm for reliable data delivery by formulating discrete times stochastic control process and deep learning techniques for UWSAN to overcome these issues. The proposed algorithm has been validated with conventional state-of-the-art methods and results show that the proposed approach exhibits its effectiveness in terms of less network overhead and propagation delay with high throughput and less energy consumption for every reliable packet transmission.

INDEX TERMS Under water acoustic sensor networks, reliable data transfer, quality of service (QoS), deep learning.

I. INTRODUCTION

Two-third portions of the earth surfaces are covered with water [1]. In the recent year's research on UWASN management has attracted significant attention to the industries and researchers due its applications in assisted navigation, data collection and off-shore/On-shore exploration, surveillance and pollution monitoring in ocean etc..,[2] the unmanned exploration is required because human manifestation impossible for monitoring and control. Now, UWASN has gained its importance whereas existing methods for terrestrial Wireless sensor networks (WSN) and Ad-hoc systems remain inappropriate for underwater application owing to its distinctiveness between communication medium and other characteristics in

The associate editor coordinating the review of this manuscript and approving it for publication was Guangjie Han.

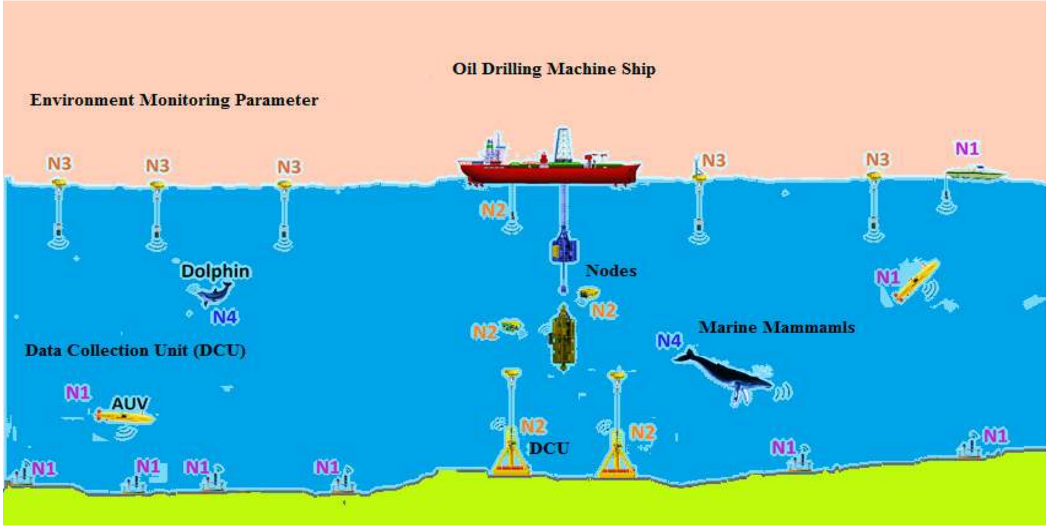

FIGURE 1. UWASN architecture.

network architecture [3], [4]. On the other hand, the rule of the routing protocols based on QoS permit sensor nodes to balance consumption of energy and certain pre-determined QoS measures before they bring data to the destination node [5]–[10]. In UWASN, reliable data transmission is highly difficult because it requires more power than WSN and battery management is highly difficult [11]–[14]. In [15] UWASN preferred Acoustic signal owing to its speed about 1800 m/s with less propagation delay and energy with constricted bandwidth whereas the radio waves are not preferable due its low frequencies (Apprx 30Hz to 300Hz) with enormous power transmission and optical waves are not preferable due to the usage of high precision laser beam for data transmission. Since optical and radio signals suffers absorptions and scattering, UWASN practices acoustic signals as a physical medium for data communications, respectively.

In this way acoustic signal is used in UWASN [16]. Some exceptional attributes of UWASN execute additional limitations for these algorithms for reliable data transmission. To begin with, the delay of the signal in the acoustic region has highest power of order five than that of radio frequency (RF) wave [17]. Second, the accessible transfer speed and bandwidth of UWASN is remarkably constrained which relies upon range of data transmission as well as recurrence [18]. Third, Bit Error proportion and signals loss would experience channel hindrances which affects the packet delivery ratio and throughput of the system [19]. These natural qualities degrade the performance of the network architecture and its resources while developing algorithms for reliable data transmission for UWASN.

However, the usage of acoustic signal in UWASN will be processed using DCU [20] with the help of various under water sensor Nodes names N_1, $\mathrm{N}_2 \ldots\ldots N_{\mathrm{m}}$ for environment monitoring and other onshore applications as shown in the Figure.1.

Though it has been used for several applications UWASN Imposes difficulties resembling propagation delay, worse transfer speed (<150 KHz), restricted battery-operated system with high Error Rate. Due to these difficulties, planning a reliable data transmission with less energy ratio is a most challenging task. Owing to the characteristics of UWASN most of the existing algorithms for reliable data transmission such as vector based forwarding (VBF), distributed underwater clustering transmission algorithm (DUCS), Relative distance based forwarding (RDBF), adaptive energy aware scheme (AEWS) and Multipath Power control transmission (MPCT) etc.. are not suitable due to the sudden breaking of cluster heads during data transmission. Hence Quality of links needs to be maintained and it should update periodically before data transmission. Motivated by the facts as discussed, we have designed an adaptive energy aware quality of service (AEA-QoS) algorithm for reliable data delivery in UWASN.

The main contribution of AEA-QoS:

- Energy and QoS trade-off has been achieved using discrete time stochastic control process (DTSCP) and deep learning techniques (DLT). So that controlled data transmission helps to improve Reliability, throughput, precision and reduces the error rate etc.
- In this approach data transmission for all the nodes is carefully chosen based on reliability of transmission link and reachability of the underwater sensor node which helps to minimize energy consumption during data transfer.
- Adaptive data holding time has been calculated using indigenous network to reduce propagation delay among sensor nodes during transmission. Besides holding time is adjusted to avoid collision in the network and it helps to increase network life time.

The contribution and structured of this research as follows: The correlated state of art conventional methods and proposed techniques has been discussed in the section-1 and Section-2, respectively. Section-III specifies the mathematical formulation and discussion on Adaptive energy aware quality of service (AEA-QoS) algorithm for reliable data delivery in UWASN. Further validations with conventional state of art methods in comparison AEA-QoS has been experimentally analyzed in the section-5 and then section-6 concludes the research with future extension.

II. LITERATURE SURVEY

In this survey we focused on few notable works on data transmission for UWASN. In [21] Location based routing approach for underwater network formulation assumes that the sensor nodes know their final source/sink 3D areas. These sensor nodes have ''Routing funnel pipes'' based source/sink associated line which is eligible to transfer the data from the source to the destination. In any case, the execution of VBF [22] is influenced by the radius range of the ''directing channel'' of the Routing pipes. In this Approach, a few nodes may exist in the transmission scope of the sender [23] whereas other nodes would be outside the routing channel which reduces the reliability of data during transmission.

In [24] geographic approach has been used in DFR which utilizes sensor flooded node inside the underwater network by restricting the quantity of sending nodes. The approach uses geographic location with flooded sensors which would be resolved with the help of source/sink nodes and forwarder current in accounted with quality of link nodes and its. In any case, alike the effect of directing funnel sweep for VBF, DFR suffers sensitively to ''High threshold angel limit'' [25] which increases the energy utilization of the sensor nodes presents in the network and excess transmissions still happens in locations with bad connect quality among the link nodes.

In [26] position centered communicated strategy which utilizes 'fitness function ''to forward the data in the nodes. The number of nodes involvement in this method is remarkably higher which increases the energy utilization of UWASN. In RDBF, all node locations are fused during data transmission along these lines, whereas sink nodes tell their location to the network instantly incurs large network overhead and collision which leads to reduce performance of the system.

In [27] authors proposed location unaware cluster head (CH) scheme approach where various leveled clusters in underwater region do not require location specification about the nodes. DUCS utilizes information accumulation in CH for energy saving and minimizes network life time as well as congestion. In DUCS sudden breaking of cluster heads occurs during data transmission. Hence Quality of links needs to be maintained and it should update periodically before data transmission. In DUCS movement of nodes develops water current which influences the structure of the groups in UWASN, therefore diminishes Network life and reliability of data. Additionally, multi-hop communication among the nodes limits its relevance and flexibility. This may prompt between clusters which lead to cluster head failure of nodes during data transmission.

In [28], [29] authors proposed **multipath virtual sink (MVS)** schemes, where numerous nearby sinks nodes are associated with a system by means of rapid connections of the underwater network based on forwarder dependent hop count schemes. However, this system experiences numerous repetitive transmissions which lead to low PDR and network overhead with more Energy utilization. Conversely, **MPT** [30] **experiences** excess data transmissions and brings about excessive network lifetime due to multipath setup.

Form conventional state of art algorithms discussion, the algorithm to achieve high PDR with less network overhead and utilization of Energy with congestion control in the sensor network has been proposed using Adaptive energy aware quality of service (AEA-QoS) algorithm by formulating discrete time stochastic control process and deep learning techniques to address the limitation of existing works.

III. ADAPTIVE ENERGY AWARE QUALITY OF SERVICE ALGORITHM FOR UWASN

In AEA-QoS, collision control mechanisms lay over the top of the transmission control layer which makes data transmission more reliable in underwater sensor network between gateway and nodes present in the architecture. As illustrate in the flow diagram as shown in the Figure.2.

Energy level of the battery has been continuously monitored by sensor node unit and Queue length information has been collected using feedback block which is in close association with queue length monitoring control block. Collision control block(CCB) is carefully chosen and it is used to control the reliability of transmission link and reachability of the data from the sensor node to gateway in the architecture. Further, Gateway is accountable for the aggregation of sensor data by managing the cluster head without break down and it sends queue length ratio to the sensor nodes back with the help of queue length monitor. The loop has been continuously monitored and data hold rate is adjusted using DTSCP and DLT as per the data transmission rate between gateway and sensor nodes as shown in the Figure.2..

A. FORMLUATION-1: COLLISION AVOIDANCE AND DATA RATE ADJUSTMENT USING DTSCP AND DLT

Adjusting data hold rate is one of the efficient techniques to mitigate collision among sensor in underwater network. This solution has been implemented using data hold rate adjustment and this accounts three significant information such as

- Length of the queue
- Gateway throughput
- Level of Battery of all the UWASN

This optimization problem has been solved using DTSCP and DLT. Here DTSCP is the modeling used in stochastic condition with partly random variables as outcomes. In UWASN, DTSCP is used to locate the level of the sensor nodes and provide leverage among sensor nodes and adjoining Environment conditions with few objectives such as individual utility

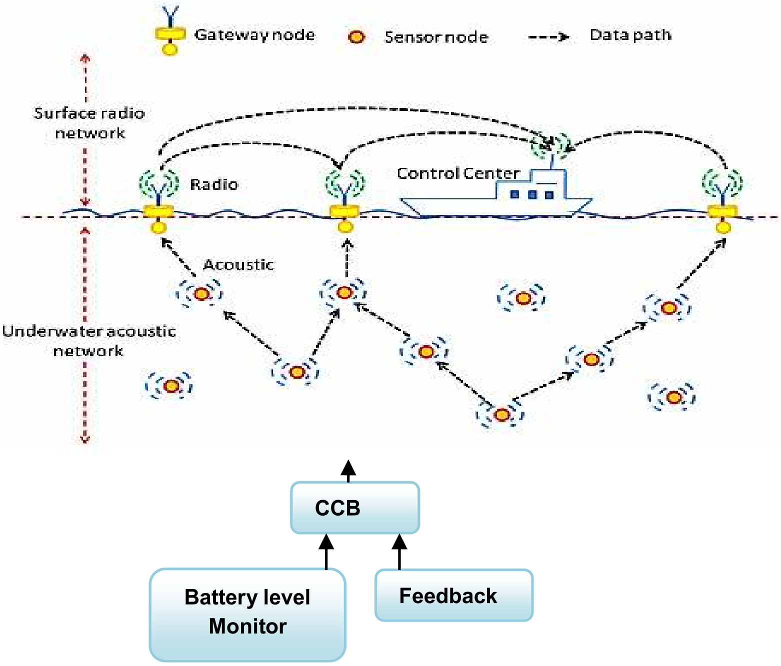

FIGURE 2. AEA-QoS control flow in UWASN.

function, action and state space as shown the Eq(1).

$$\begin{aligned} \mathbf{f(x)_{EL}} &= \mathbf{Weight_{EL}*Uf(x)_{EL}} \\ \mathbf{f(x)_{T}} &= \mathbf{Weight_{T}*Uf(x)_{T}} \\ \mathbf{f(x)_{Q}} &= \mathbf{Weight_{Q}*Uf(x)_{Q}} \\ \mathbf{Uf(x)} &= \sum \mathbf{f(x)_{EL}*f(x)_{T}*f(x)_{Q}} \end{aligned} \tag{1}$$

- Where $f(x)_{EL} * f(x)_{T} * f(x)_{Q}$ is the function which denotes energy level (En), Throughput (Th) and length of the queue(Q) at the gateway point of the UWASN.
- Weight_{EL}, Weight_{T}, Weight_{Q} is the weight of the energy level, Throughput and length of the queue at the gateway point

From the Eq(1) it is note that

$$\mathbf{W} = \mathbf{Weight_{EL}}, \quad \mathbf{Weight_{T}}, \ \mathbf{Weight_{Q}} = 1 \tag{2}$$

Then En_{Max} and $\text{En}_{\min}$ can be calculated using utilization function as formulated in the Eq(1),

$$\text{Hence, } \mathbf{Uf(En)} = \frac{\mathbf{E-En_{min}}}{\mathbf{En_{max}-En_{min}}} \tag{3}$$

In the same way the throughput of the sensor node has been calculate using this utility function as shown in the Eq(4) and algorithm.1,

$$\mathbf{Uf(T)} = \begin{cases} \mathbf{x} = 0, & Th < Th(\mathbf{min}) \\ \mathbf{x} = 1 - €, & Th(\mathbf{min}) \leq \mathbf{Th} < Th(\mathbf{min}) \end{cases} \tag{4}$$

Finally the length of the Queue at the gateway point will be calculated using Eq(5),

$$\mathbf{Uf(Q)} = \frac{\mathbf{\emptyset_{max}} - \emptyset}{\mathbf{\emptyset_{max}}}$$
$$\text{where } \emptyset, \mathbf{\emptyset_{max}} \text{ is the number of packets in the Queue} \tag{5}$$

Algorithm 1 Throughput Utility Function for UWASN

```
Input Th,Th(min) and Th(max)
Output x
Begin
If (Th<Th(min))
X=0
Elseif(Th( min ≤ Th< Th(min
X=1-€
*Where€ = $\exp^{\frac{-\partial+Th^2}{\beta+Th}}$
//*∂ and β are the Positive parameter for Th calculation * //
Else
X=0
End if
End begin
```

From the Eq., (1 to 5) the optimum values estimation has been mathematically verified using deep learning technique through employing decision making function to define the selection policy of the sensor node for reliable data transmission with high throughput, precision and reduces the error rate etc..

The decision maker function check the packets send by the sensor node from gateway and it ensure its estimated hold rate using Queue length monitoring block as discussed in the Figure.1. Accumulated values in the queue has been evaluated using utility function of energy level, throughput and queue length using iterative solutions as discussed in the algorithm 2.

From the above discussed mathematical formulation for the data transfer between the nodes and the gateway is at

Algorithm 2 Energy Aware Deep Learning Collision Control System for UWASN

```
Attributes:
Rate of learning is termed asp-> "α"
Batter level ->Bat(max) and Bat(min)
D( $Sen'_o Rate_o$)-> is the random variable defines
sensor node data->$Sen_o$
Data hold rate-> $Rate_o$
Check if (Data hold rate)
    $Uf(x) = \sum f(x)_{EL} * f(x)_T * f(x)_Q$
Decision access node ($Sen'_o Rate_o$)
Wait for the data check at gateway at T+1 time interval
Decision access node-> ($Sen'_{T+1} Rate_{T+1}$)
Q(P,A)
Where P -> Position or location of the node
A-> Node rate of action
$Q(Sen'_T Rate_T)=Q(Sen'_T Rate_T)+ \alpha(R(Sen'_T Rate_T)+¥max(Q(Sen'_{T+1} Rate_{T+1})-Q(Sen'_T Rate_T)$
Since $\rightarrow$ $Uf(\alpha\ \mathcal{C}\ ¥) = Uf(\alpha(R(Sen'_T Rate_T)+¥max(Q(Sen'_{T+1} Rate_{T+1}))$
$Q(Sen'_T Rate_T)=Q(Sen'_T Rate_T)+Uf(\alpha\ \mathcal{C}\ ¥)- Q(Sen'_T Rate_T)$
Repeat (Loop)
```

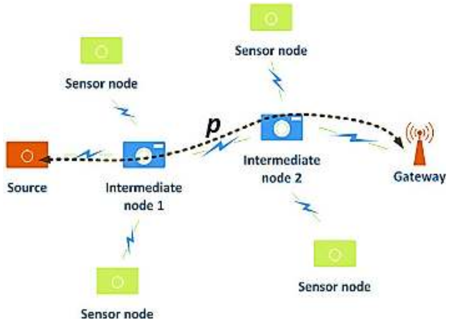

FIGURE 3. UWASN for testing.

the time interval "T" and "T+1" has been estimated using decision access node as shown in the Eq(6&7)

$$\textbf{Decision access node} - > (\textbf{Sen}'_{\textbf{T}}\textbf{Rate}_{\textbf{T}}) \tag{6}$$

$$\textbf{Decision access node} - > (\textbf{Sen}_{\textbf{T+1}'}\,\textbf{Rate}_{\textbf{T+1}}) \tag{7}$$

The node of action has been evaluated using "T "and "T+1" time for the data transfer to check the reliability of data with less energy consumption in UWASN. Using the Eq(8) and Eq(9).

$$\begin{aligned}\mathbf{Q(Sen_{T'}\ Rate)_T} &= \mathbf{Q(Sen_{T'}\ Rate)_T + Uf\,(\alpha + ¥)} \\ &\quad - \mathbf{Q(Sen_{T'}\ Rate)_T} \qquad (8) \\ \mathbf{Q(Sen_{T+1'}\ Rate)_{T+1}} &= \mathbf{Q(Sen_{T+1'}\ Rate)_{T+1} + Uf\,(\alpha + ¥)} \\ &\quad - \mathbf{Q(Sen_{T+1'}\ Rate)_{T+1}} \qquad (9)\end{aligned}$$

Hence this reinforce mathematical modeling of deep learning using decision function using access nodes helps to optimize energy level of UWASN with reliable data transfer.

B. FORMULATION-2: RELIABILITY OF TRANSMISSION LINK AND REACHABILITY OF THE UNDERWATER SENSOR USING

The positional value is used to calculate the reliability of the data where the transmission link can be calculated using outbound and inbound ratio. It is noted that higher the positional value of the node will increase the reliability of the links in the network using intermediate nodes as shown in the figure.3.

Based on the $Source_{id}$, $sink_{id}$, $Request_{id}$, data transfer between nodes to be initiated based on uplink transmission ratio.

Let us consider 'i' be the sender node and 'j' be the receiver node and 'L' is the length of the Queue. Where N is the sensor node $= \{N_o, N_1 \ldots . N_L\}$, the outbound link length (ϵ_L) has been formulated using Eq(10)

$$\textbf{outbound} = \sum \epsilon_{\mathbf{jL}}(\mathbf{source_{id}}, \mathbf{sink_{id}}, \mathbf{Request_{id}}) \tag{10}$$

$$\epsilon_{\mathbf{L}} = \sum\nolimits_0^{\mathbf{L}} (\mathbf{i}, \mathbf{j})_{\mathbf{L}} \tag{11}$$

Normalized outbound link length ϵ_L) is the ratio of the minimum and maximum hop and it is used to defines the traffic congestion in uplink as shown in the Eq(12)

$$\mathbf{N\epsilon_{jL}} = \frac{\epsilon_{\mathbf{jL}}}{\sum_{\mathbf{0,}}^{\mathbf{L}} (\mathbf{i}, \mathbf{j_L} * Source_{id}, sink_{id}, Request_{id}} \tag{12}$$

The data transmission reachability has been estimated using hop counts where "i" and "j" received the node based on the $\text{Request}_{\text{id}}$ and next hop has been calculated as $N\epsilon_{ij} = \epsilon_{ij} + \epsilon_j$ and this cost function estimated with minimum time for the node to transfer data without loss as shown in Eq(13).

$$\mathbf{NCost(\epsilon)_{ij}} = \frac{\mathbf{Source_{id}, Request_{id}\ from\ j}}{\mathbf{sink_{id}\ from\ j\ to\ L}} \tag{13}$$

Let us consider the node "i" is the sender which needs to transfer data to the receiver node "j" with the time interval "T" as shown in the Eq(14),

$$\mathbf{Cost}(\epsilon_{\mathbf{ij}}) = \frac{\mathbf{D_f}}{\mathbf{S_i}} \tag{14}$$

where $\frac{D_f}{S_i}$ is the data forward and send ratio based on receiver replies for the data transmission between the node at the time inter "T+1" is represented as exponential factor in the Eq(15)

$$\begin{aligned}\mathbf{Cost}(\epsilon_{\mathbf{ij}}) \\ = \begin{cases} \mathbf{Weights*Cost}(\epsilon_{\mathbf{ij}})\mathbf{T}+\,(\mathbf{1}-\mathbf{Weights}) \\ \mathbf{*Cost}(\epsilon_{\mathbf{ij}})\,(\mathbf{T}-\mathbf{1})\,, & 1 < T > 0\,. \\ \mathbf{Cost}(\epsilon_{\mathbf{ij}})\mathbf{T}, & \textit{otherwise} \end{cases}\end{aligned} \tag{15}$$

Hence each and every nod in the UWASN needs to follow the Request and reply concept of sending and receiving data by the gateway for reliable data transfer with high reachability.

C. FORMULATION-3. ADAPTIVE DATA HOLDING TIME HAS BEEN CALCULATED BASED ON LOCAL NETWORK SPECIFICATION

In the adaptive approach data holding time can be estimated based on waiting and discovering time of the nodes present in the network and level of data transmission during forwarding control has been calculated using Quality of service (Qos) aware queuing model.

Algorithm 3 QoS Aware Modelling

```
Input: $R_{1(s,d)}$- Data from source to destination
Output: Reliable Next Hop data point (NHP), Next hop(NH).
Begin
If (OP)
Data send to NH
Else If ($R_{1(s,d)}$>OP)
Data send to $NHP_1$
elseIf ($R_{2(s,d)}$>OP)
Data send to $NHP_2$
elseIf ($R_{3(s,d)}$>OP)
Data send to $NHP_1$,$NHP_2$,$NHP_3$....
Else
Drop the data packets
End if
End begin
```

In QoS aware modelling the choosing of proper hop is estimated based reliability sensitivity packets (RSP)and ordinary packets (OP) as shown in the algorithm.3.

In the QoS metrics the queue is estimated in two categories where if the RSP > OP the data packets with highest priority has been sent to the sink node for processing. In another case if RSP < OP the data packets will be send provided if the queue is nullified or empty. If the RSP fails to send the data to the sensor nodes of underwater region OP takes an account to send the data to the corresponding node via gateway to match QoS for reliable data transfer with less energy utilization as shown in the algorithm.3.

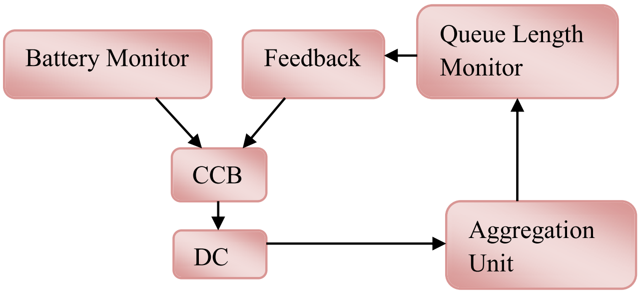

FIGURE 4. System control flow architecture.

Once the packets has been received based on RSM and OP the packets in the buffer has been calculated based on "request/reply" controls in the buffers based on adaptive data hold rate estimation as shown in the Eq(16)

$$\mathbf{NCost}(\epsilon)_{\mathbf{ij}} = \frac{\mathbf{Source_{id}, Request_{id}\ from\ j}}{\mathbf{sink_{id}\ from\ j\ to\ L}} \tag{16}$$

where "i, j" -> Resembles the node in UWASN where based on the request control the next possible hop is identified by the "i" node with adaptive data hold rate in accordance with reply response from the node "j" node.

From the discussion the link quality and reachability can be improved through data hold rate and optimizing delay in the network of the stored packets as shown in the Eq(17)

$$A_D = \frac{1}{N}\sum\nolimits_{A=1}^{N} T_c - T_A \tag{17}$$

where A_D the average delay with the Total current time and arrival time is represented as $T_c - T_A$. The difference is estimated at "N^{th}" items stored in the buffers. If data stored i.e., hold rate time in the buffer is high leads to increase the reliability of data which is calculated based on service request time as shown in the Eq(18) and adaptive timer is shown in the Figure 5

$$\mathbf{Cost}(\epsilon)_{\mathbf{SR}} = \frac{\mathbf{N(packets\ in\ Buffer)}}{\mathbf{Rate\ of\ service}(\mathbf{R_s})} \tag{18}$$

Algorithm.4. Clearly defines the hold time calculation for the data in UWASN. The maximum hold is set by system administrator. The buffer time ($\mathbf{Cost}(\epsilon_{\mathbf{SR}})$ is calculated based on the ratio of data rate at buffer in the Queue with the difference between $\mathbf{Cost}(\epsilon)_{\mathbf{SR}} - \mathbf{B_{F(max)}}$ **as shown in the Eq(19)**

where $\mathbf{Cost}(\epsilon)_{\mathbf{SR}} - \mathbf{B_{F(max)}} = \mathbf{B_{F(T)}}$

$$\mathbf{B_{Fill(T)}} = \frac{\mathbf{B_{F(T)}}}{\beta R} \tag{19}$$

From the filled data the service rate of the data hold duration in the access node can be calculated using Eq(20)

$$\mathbf{H_D} = \prod\nolimits_{\mathbf{H(min))}}^{\mathbf{H(max)}} \mathbf{1}-\mathbf{exp}^{\frac{\mathbf{Cost}(\epsilon_{\mathbf{SR}})}{\mathbf{H(max)+1*}}}\mathbf{H_C} \tag{20}$$

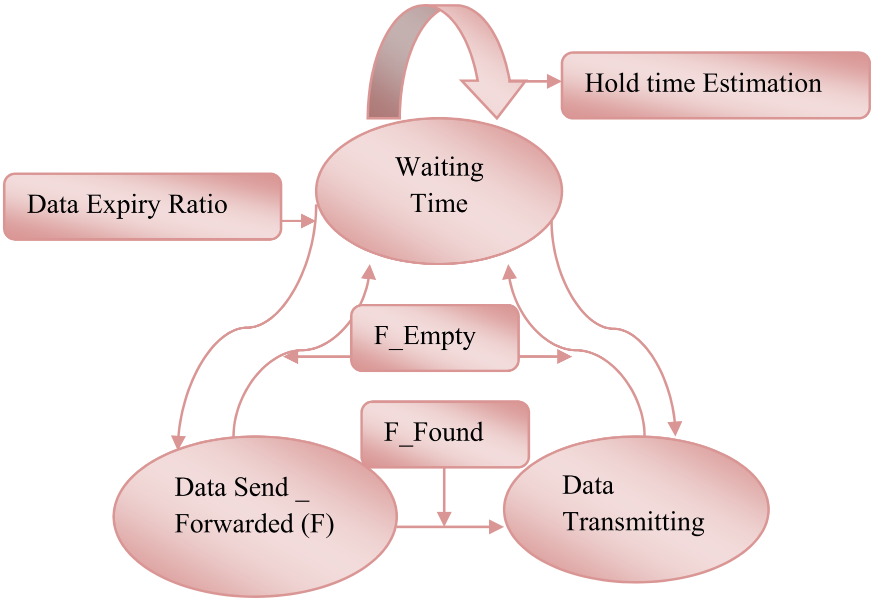

FIGURE 5. Adaptive timer for UWASN.

Algorithm 4 Adaptive Data Hold Rate Optimization Algorithm

```
Inputs variable $\epsilon_{SR}$, $\beta_R L_T$
Where,
Expire Rate of the packet-> $\beta_R$
$L_T$-> Time of last packet
Output checks data hold rate
If(packets _received)
Do:
    $A_D = \frac{1}{N}\sum_{A=1}^{N} T_c - T_A$
    $Cost(\epsilon_{SR}) = \frac{N(packets\ in\ Buffer)}{Rate\ of\ service(R_s)}$
If($\epsilon_{SR}$>1) then
$T_D$(Tine difference) = hold Duration ($H_D$)- Current Time ($C_T$)-last time ($L_T$)
If($T_D$>0 &&$\beta_R$>($H_D + T_D$))
$H_{D=}T_D$
Endif
Endif
Else calculate hold time $H_T$
If ($C_T + H_T$) <$\beta_R$
$H_T$<-0
End if
Check the failures by repeating the above steps
End if
If ($H_D || \beta_R \neq 0$)
$L_T = C_T$
Endif
```

where

$$\mathbf{H_C = 2(\frac{H_D}{Hop\ (count) + 1})} \tag{21}$$

sub Eq (21) in Eq(22)

$$\mathbf{H_D = \prod_{H(\max)}^{H(\min))} 1 - exp^{\frac{Cost(\epsilon_{SR})}{H(\max)+1*}} 2(\frac{H_D}{Hop\ (count) + 1})} \tag{22}$$

TABLE 1. Simulation settings.

Parameters	Range
Propagation range	2000 m/s
Power transmission	1.5 Watts
Model of antenna	Omni- directional
Transmission range	250 m
Traffic model	Constant bit rate
Size of Packet	250 B
Energy	900 J
Queue Time	1 sec
Sensor Count	50
Simulation time	900 sec

From the Eq(22) it is clear lower the data loss is due to link reliability and less disruption. Hence effective data rate is maintained using adaptive service rate and arrival rate based in hop counts (min and max values).As the propagation delay increases with hop count which helps to compensate the data hold rate and reduce the loss of data in UWASN.

From the discussion the "request", "reply" and "data" packets has been calculated using Eq(23)

$$\mathbf{f}\,(\mathbf{x}) = \begin{cases} \mathbf{Time_{rq}+Time_{rp}+Time_{data}+3XTime_{P}} & \textit{request} \\ \mathbf{Time_{rp}+Time_{data}+2XT_{P}}, & \textit{reply} \end{cases} \tag{23}$$

where

$\mathrm{Time_{rq}}\rightarrow$ Time required for sender node

$\mathrm{Time_{rp}}\rightarrow$ Time required for forwader

$\mathrm{Time_{data}}\rightarrow$ Time required for senderforstoreddata

$\mathrm{Time_{P}}\rightarrow$ Propagation time

Here in this adaptive approach during each transmission the data packets are aggregated in the buffer which prevents unwanted transmission to reduce collision in the UWASN for reliable data transfer.

IV. RESULTS AND DISCUSSIONS

The proposed approach is experimentally validated using simulation modelling using Network simulator and Simulink. Here each node in the UWASN has battery backup which employs reliable communication in the network.

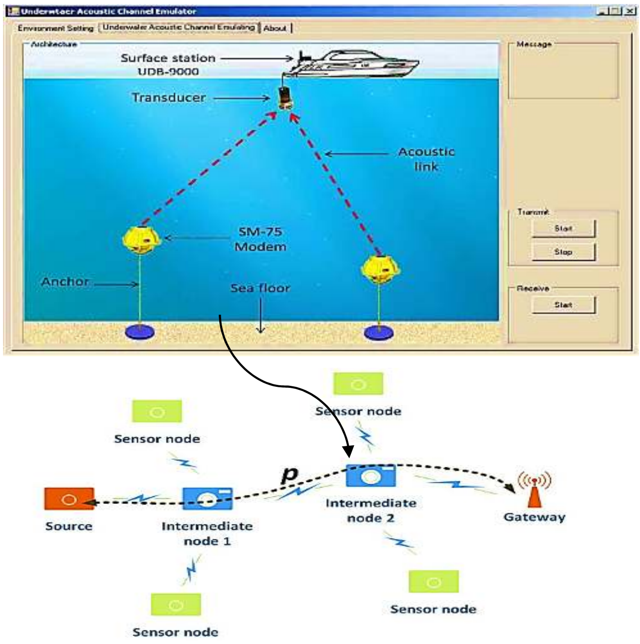

FIGURE 6. Graphic user interface (GUI)-UDB 9000 [21].

During Experimental analysis we have developed an Graphic user interface (GUI) in reference with WiNes Lab [31], [32] as shown in the figure.6. During experimental analysis SM-75 acoustic modem has been interfaced in the controller and UDB 9000 has been utilized.

The simulation network has been created using with 20 to 50 sensor nodes with 250 × 250 area in underwater environment as represented in GUI of the Figure.6. respectively. Here the sensor nodes are energized with 900J with the maximum data rate of 2 Mbps and simulation time of 900 sec. The traffic model used in this approach is constant bit rate with omni-directional antenna. Various factors such as throughput, Queue length, Bit error rate, packet delivery ratio, precision, End to end delay, routing overhead, energy per received packets are analysed.

$$\mathbf{PDR} = \frac{\mathbf{N(Rxp)}}{\mathbf{N(Txp)}} \qquad (24)$$

In the Eq (24),

PDR represents as the packet delivery ratio

N (Rxp) −received packets *Count*

N (Txp) −transmitted packets *Count*

In the conventional techniques such as vector based forwarding (VBF), distributed underwater clustering transmission algorithm (DUCS), Relative distance based forwarding (RDBF), adaptive energy aware scheme(AEWS) and Multipath Power control transmission (MPCT) shows decreased PDR due to large number of collision in the network. The number of forwarding nodes causes high density at the source end which fixed data hold time increase the PDR. The proposed AEA-QoS achieved higher PDR due to the considerable amount of time taken to calculate the data hold time in the network. This reduces collision and improves PDR. Thus; Figure.7 shows that the AEA-QoS is more effective than existing state of art techniques.

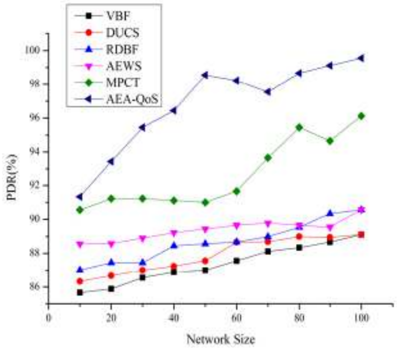

FIGURE 7. PDR V network size analysis.

Increased network traffic in the conventional techniques such as VBF, DUCS RDBF, AEWS and MPCT impacts on propagation delay where as in the proposed AEA-QoS the congestion and network traffic has been controlled with fixed amount of time through discrete times Stochastic control process and deep learning techniques with reinforce mathematical modelling using decision function as mathematically formulated in the Eq (8 &9) and the illustration for the two nodes Sender->x(t) at time internal "t" and "t+1" and receiver->y(t) at time interval "t" and "t+1" is depicted the figure.8.

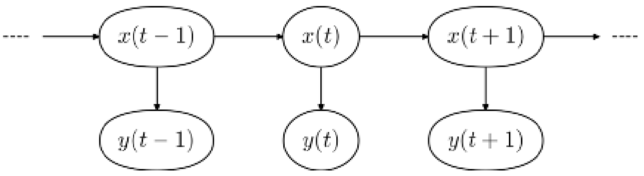

FIGURE 8. Discrete times stochastic control process mathematical modelling for sender and receiver.

In AEA-QoS the arrival rate and expiry rate has been calculated based on adaptive the hold time which dynamically varies according to the fixed packets which helps to reduce network traffic in link nodes and increases the reachability. The graphical representation of the proposed algorithm has shown in the figure.9.

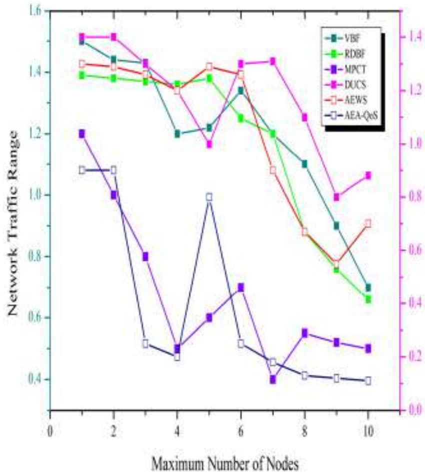

FIGURE 9. network traffic analysis for the conventional and AEA-QoS approach.

In QoS aware modelling, the choosing the proper hop is estimated based on reliability sensitivity packets (RSP) and ordinary packets (OP) in **AEA-QoS approach**, if RSP>OP then the highest priority of data packets sent to the sink node for processing. In an alternative case if RSP<OP then the data packets will be send provided if the queue is nullified or empty. If the RSP fails to send the data to the sensor nodes of underwater region OP takes an account to send the data to the corresponding node via gateway to match QoS for reliable data [33] transfer made the energy utilization less than the conventional VBF, DUCS RDBF, AEWS and MPCT approaches as shown in the figure.10.

In the conventional techniques the adaptive hold time for a data is fixed which in turn increases the routing overhead of a network. In Adaptive approach data holding time can be estimated based on waiting and discovering time of the nodes present in the network and level of data transmission during forwarding control has been calculated using Quality of service (Qos) aware queuing model. based on the various measurements as shown in the algorithm.2 and Eq(6 &7), AEA-QoS approach has moderate data hold

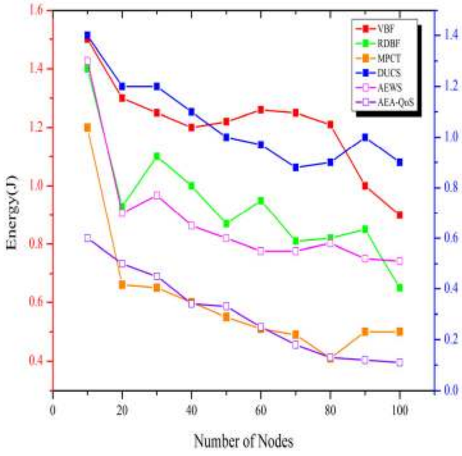

FIGURE 10. Energy utilization for the conventional and AEA-QoS approach with network size analysis.

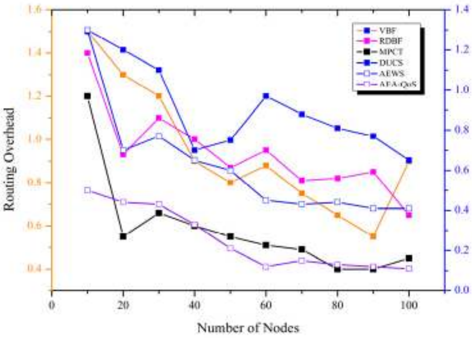

FIGURE 11. Routing overhead of AEA-QoS approach with network size.

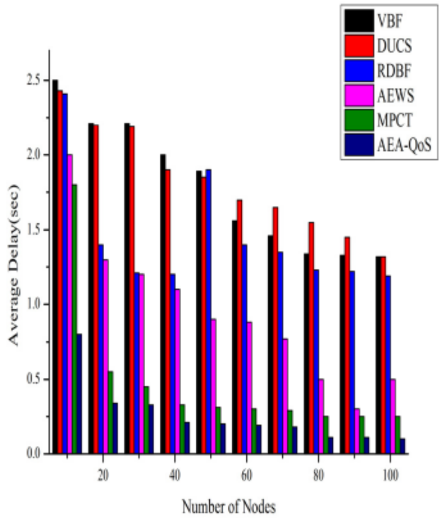

FIGURE 12. Average delay vs network size.

time rate which reduces the routing overhead than VBF, DUCS RDBF, AEWS and MPCT approaches as shown in the Figure.11.

Average packet delay is the metric which is utilized to ascertain **a** time to transmit the data [34], [35] from source hub to destination hub. The normal average time is determined for each packet transmission [36], [37] in the system. The delay time is evaluated as below in the Eq (25 & 26),

$$\mathbf{packet\_delay(PA_D)} = \mathbf{Rxt_{destn}} - \mathbf{Txt_{source}} \tag{25}$$

$$\mathbf{D} = \sum \frac{\mathbf{PA_D}}{\mathbf{N(Rxp)}} \tag{26}$$

In the above Eq (25 & 26),

- **$\mathbf{PA_D}$represents as the packet delay**
- **$\mathbf{Rxt_{destn}}$ is the time of reception at destination**
- **$\mathbf{Txt_{source}}$ is the Time of Tranmission at source**
- **d is the average delay**
- **N (Rxp) Received packet count**

In this research AEA-QoS data hold rate time in the buffer which leads to increase the reliability of data which is calculated based on service request time [38], [39] with less packet delay as shown in the Eq (18) and graphical representation as shown in the figure.12.

V. CONCLUSION

This research uses AEA-QoS for reliable data transmission in UWASN. AEA-QoS utilizes discrete times Stochastic control process and deep learning techniques to increase throughput and network lifetime as well reduce utilization of Energy in UWASN by choosing sensor nodes data based on data transfer and link reliability. Though conventional state of art conventional techniques are not suitable due to the sudden breaking of cluster heads during data transmission. Hence Quality of links needs to be maintained and it should update periodically before data transmission to reduce CH breaks in UWASN. Hence the proposed approach has high reliable data delivery with less overhead and energy utilization suits more opted for UWASN. Optimized Data retrieving at the ferry nodes to maximize the data delivery ratio will be extended in future scope of this research.

REFERENCES

[1] H. U. Yildiz, V. C. Gungor, and B. Tavli, "Packet size optimization for lifetime maximization in underwater acoustic sensor networks," *IEEE Trans. Ind. Informat.*, vol. 15, no. 2, pp. 719–729, Feb. 2019.

[2] W. Kim, H. W. Moon, and Y. J. Yoon, "Adaptive triangular deployment of underwater wireless acoustic sensor network considering the underwater environment," *J. Sensors*, vol. 2019, Feb. 2019, Art. no. 6941907.

[3] S. Han, Y. Noh, U. Lee, and M. Gerla, "Optical-acoustic hybrid network toward real-time video streaming for mobile underwater sensors," *Ad Hoc Netw.*, vol. 83, pp. 1–7, Feb. 2019.

[4] D. A. Abraham, "Underwater acoustics," in *Underwater Acoustic Signal Processing*. Cham, Switzerland: Springer, 2019, pp. 95–199.

[5] S. K. S. L. Preeth, R. Dhanalakshmi, R. Kumar, and P. M. Shakeel, "An adaptive fuzzy rule based energy efficient clustering and immune-inspired routing protocol for WSN-assisted IoT system," *J. Ambient Intell. Humanized Comput.*, to be published. doi: 10.1007/s12652-018-1154-z.

[6] O. Said, "Performance evaluation of WSN management system for QoS guarantee," *EURASIP J. Wireless Commun. Netw.*, vol. 2015, no. 1, p. 220, Dec. 2015.

[7] A. Rahim, T. Qiu, Z. Ning, J. Wang, N. Ullah, A. Tolba, and F. Xia, "Social acquaintance based routing in vehicular social networks," *Future Gener. Comput. Syst.*, vol. 93, pp. 751–760, Apr. 2019.

[8] O. Said and A. Tolba, "Design and performance evaluation of mixed multicast architecture for Internet of Things environment," *J. Supercomput.*, vol. 74, no. 7, pp. 3295–3328, Jul. 2018.

[9] S. M. A. El-Att, "Efficient packet scheduling with pre-defined QoS using cross-layer technique in wireless networks," in *Proc. 11th IEEE Symp. Comput. Commun. (ISCC)*. Jun. 2006, pp. 820–826.

[10] B. Jedari, F. Xia, H. Chen, S. K. Das, A. Tolba, and Z. Al-Makhadmeh, "A social-based watchdog system to detect selfish nodes in opportunistic mobile networks," *Future Gener. Comput. Syst.*, vol. 92, pp. 777–788, Mar. 2019.

[11] X. Bai, I. Lee, Z. Ning, A. Tolba, and F. Xi, "The role of positive and negative citations in scientific evaluation," *IEEE Access*, vol. 5, pp. 17607–17617, 2017.

[12] P. M. Shakeel, "Neural networks based prediction of wind energy using pitch angle control," *Int. J. Innov. Sci. Eng. Res. (IJISER)*, vol. 1, no. 1, pp. 33–37, 2014.

[13] X. Bai, F. Zhang, J. Hou, F. Xia, A. Tolba, and E. Elashkar, "Implicit multi-feature learning for dynamic time series prediction of the impact of institutions," *IEEE Access*, vol. 5, pp. 16372–16382, 2017.

[14] P. Gomathi, S. Baskar, M. P. Shakeel, and S. V. R. Dhulipala "Numerical function optimization in brain tumor regions using reconfigured multi-objective bat optimization algorithm," *J. Med. Imag. Health Informat.*, vol. 9, no. 3, pp. 482–489, Mar. 2019.

[15] S. S. Rahim, S. Ahmed, N. Javaid, A. Khan, N. Siddiqui, F. Hadi, and M. A. Khan, "Scalability analysis of depth-based routing and energy-efficient depth-based routing protocols in terms of delay, throughput, and path loss in underwater acoustic sensor networks," in *Recent Trends and Advances in Wireless and IoT-Enabled Networks*. Cham, Switzerland: Springer, 2019, pp. 171–185.

[16] T. Islam and Y. K. Lee, "A cluster based localization scheme with partition handling for mobile underwater acoustic sensor networks," *Sensors*, vol. 19, no. 5, p. 1039, Feb. 2019.

[17] H. Nam, "Data-gathering protocol-based AUV path-planning for long-duration cooperation in underwater acoustic sensor networks," *IEEE Sensors J.*, vol. 18, no. 21, pp. 8902–8912. Nov. 2018.

[18] W. Aman, M. M. U. Rahman, J. Qadir, H. Pervaiz, and Q. Ni, "Impersonation detection in line-of-sight underwater acoustic sensor networks," *IEEE Access*, vol. 6, pp. 44459–44472, 2018.

[19] R. Kumar, K. S. Sankaran, R. Sampath, and P. M. Shakeel, "Analysis of regional atrophy and prolong adaptive exclusive atlas to detect the alzheimers neuro disorder using medical images," *Multimed. Tools Appl.*, to be published. doi: 10.1007/s11042-019-7213-4.

[20] H.-N. Dai, H. Wang, H. Xiao, Z. Zheng, Q. Wang, X. Li, and X. Zhuge, "On analyzing eavesdropping behaviours in underwater acoustic sensor networks," in *Proc. 11th ACM Int. Conf. Underwater Netw. Syst.*, Oct. 2016, p. 53.

[21] R. Bu, S. Wang, and H. Wang, "Fuzzy logic vector–based forwarding routing protocol for underwater acoustic sensor networks," *Trans. Emerg. Telecommun. Technol.*, vol. 29, no. 3, p. e3252, Mar. 2018.

[22] D. Wang, R. Xu, X. Hu, and W. Su, "Energy-efficient distributed compressed sensing data aggregation for cluster-based underwater acoustic sensor networks," *Int. J. Distrib. Sensor Netw.*, vol. 12, no. 3, p. 19, Mar. 2016.

[23] N. L. Venkataraman, R. Kumar, and P. M. Shakeel, "Ant lion optimized bufferless routing in the design of low power application specific network on chip," in *Circuits, Systems, and Signal Processing*. Springer, 2019. doi: 10.1007/s00034-019-01065-6.

[24] S. Baskar, S. Periyanayagi, P. M. Shakeel, and V. R. S. Dhulipala "An energy persistent range-dependent regulated transmission communication model for vehicular network applications," *Comput. Netw.*, vol. 152, pp. 144–153, Apr. 2019. doi: 10.1016/j.comnet.2019.01.027.

[25] M. Y. Durrani, R. Tariq, F. Aadil, M. Maqsood, Y. Nam, and K. Muhammad, "Adaptive node clustering technique for smart ocean under water sensor network (SOSNET)," *Sensors*, vol. 19, no. 5, p. 1145, Mar. 2019.

[26] U. Ullah, A. Khan, S. M. Altowaijri, I. Ali, A. U. Rahman, Vijay Kumar V., and H. Mahmood, "Cooperative and delay minimization routing schemes for dense underwater wireless sensor networks," *Symmetry*, vol. 11, no. 2, p. 195, Jan. 2019.

[27] A. Khan, S. Ahmad, M. Khan, M. A. Jan, Z. A. Khan, and M. U. Akhtar "EH-ARCUN: Energy harvested analytical approach towards reliability with cooperation for underwater WSNs," in *Recent Trends and Advances in Wireless and IoT-Enabled Networks*. Cham, Switzerland: Springer, 2019, pp. 147–157.

[28] A. Nayyar, V. Puri, and D. N. Le "Comprehensive analysis of routing protocols surrounding underwater sensor networks (UWSNs)," in *Data Management, Analytics and Innovation*. Singapore: Springer, 2019, pp. 435–450.

[29] M. T. R. Khan, S. H. Ahmed, Y. Z. Jembre, and D. Kim "An energy-efficient data collection protocol with AUV path planning in the Internet of underwater things," *J. Netw. Comput. Appl.*, vol. 135, pp. 20–31, Jun. 2019.

[30] H. U. Yildiz, "Maximization of underwater sensor networks lifetime via fountain codes," *IEEE Trans. Ind. Informat.*, to be published.

[31] N. Goyal, M. Dave, and A. K. Verma "Protocol stack of underwater wireless sensor network: Classical approaches new trends," *Wireless Pers. Commun.*, vol. 104, no. 3, pp. 995–1022, Feb. 2019.

[32] E. Demirors, J. Shi, R. Guida, and T. Melodia, "SEANet G2: Toward a high-data-rate software-defined underwater acoustic networking platform," in *Proc. ACM Conf. Underwater Netw. Syst. (WUWNet)*, Shanghai, China, Oct. 2016, p. 12.

[33] E. Demirors and T. Melodia, "Chirp-Based LPD/LPI underwater acoustic communications with code-time-frequency multidimensional spreading," in *Proc. ACM Conf. Underwater Netw. Syst. (WUWNet)*, Shanghai, China, Oct. 2016, p. 9.

[34] A. Tolba, "Content accessibility preference approach for improving service optimality in Internet of vehicles," *Comput. Netw.*, vol. 152, pp. 78–86, Apr. 2019.

[35] Y. Su, R. Fan, X. Fu, and Z. Jin, "DQELR: An adaptive deep Q-network-based energy- and latency-aware routing protocol design for underwater acoustic sensor networks," *IEEE Access*, vol. 7, pp. 9091–9104, 2019.

[36] S. M. A. El-Atty and Z. M. Gharsseldie, "Performance analysis of an advanced heterogeneous mobile network architecture with multiple small cell layers," *Wireless Netw.*, vol. 23, no. 4, pp. 1169–1190, May 2017.

[37] Y. Kryftis, G. Mastorakis, C. X. Mavromoustakis, J. M. Batalla, E. Pallis, and G. Kormentzas, "Efficient entertainment services provision over a novel network architecture," *IEEE Wireless Commun.*, vol. 23, no. 1, pp. 14–21, Feb. 2016.

[38] A. M. Ahmed, X. Kong, L. Liu, F. Xia, S. Abolfazli, Z. Sanaei, and A. Tolba, "BoDMaS: Bio-inspired selfishness detection and mitigation in data management for ad-hoc social networks," *Ad Hoc Netw.*, vol. 55, pp. 119–131, Feb. 2017.

[39] Y. Liu, G. Fang, H. Chen, L. Xie, R. Fan, and X. Su, "Error analysis of a distributed node positioning algorithm in underwater acoustic sensor networks," in *Proc. 10th Int. Conf. Wireless Commun. Signal Process. (WCSP)*, Oct. 2018, pp. 1–6.

• • •