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A Study on FBR Protocol for IoT in underwater Environments

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ABSTRACT

In the Internet of Things (IoT), the Internet of Underwater Things (IoUT) are smart underwater objects that can be interconnected. Environmental monitoring, underwater exploration, and disaster prevention are just a few practical applications that will be enabled by IoUT. It is recognized that IoUT is a promising technology for the development of smart cities because of its applications. Among the promising networking systems for supporting IoUT is the Underwater Wireless Sensor Network (UWSN). In contrast to traditional Territorial Wireless Sensor Networks (TWSN), UWSNs operate globally. IoUT will be faced with these unique properties. We explore IoUT in detail in this paper. The unique characteristics of underwater sensor networks (UWSNs), providing scalable and efficient routing services is very challenging. Due to the nature of radio signals in water, UWSNs use acoustic channels for communications. There are many orders of magnitude longer propagation delays in acoustic channels compared to radio-frequency channels. To address the challenging problem of routing in UWSNs, some routing protocols have been proposed. This protocol will increase the dynamic nature of routing in UWSN. This protocol subsequently displays a significant improvement in performance. The paper considers IoT applications for underwater environments using the carry-store-forwarding paradigm of Delay Tolerant Networking (DTN). The flooding of messages is one characteristic of routing protocols for DTN. As a result, the odds of delivery are increased, but on the other hand, each node has overhead in its buffer. Additionally, forwarding and receiving nodes have to spend a disproportionate amount of energy on this. By simulations, FBR protocol performance is evaluated for different angles and applications for Focused Beam Routing.

Keywords : Underwater environment, Delay tolerant network (DTN), Focused Beam Routing (FBR), FBR the ONE simulator, Internet of Things (IoT), Internet of Underwater Things (IoUT), Underwater Wireless Sensor Networks (UWSN), Protocol, Sensor, Nodes.

1.INTRODUCTION

A recent development in interconnectivity of devices is the Internet of things (IoT). Recent years have seen the use of the internet spread into more areas of daily life [5]. There are a lot of objects in our modern world that can send, receive, and process data. Engineering, medicine, and safety are just a few of the sectors and use cases we cover [5]. The concept of a global networking platform has already come a long way with smart objects communicating with each other. IoT uses wireless sensor networks and nodes that connect people and things, making information systems possible [5].

Interaction between social media and the internet will be fluid and useful. This will enable the development of new services and applications. As the internet of things has advanced, the smart device concept has increased in popularity [8]. Connected devices have a wider reach thanks to the Internet [8]. A major objective of IoT is to make the operation of all electronic equipment or things around us simpler, more intuitive, and more streamlined [8]. Energy consumption needs to be reduced in IoT devices with limited resources [9]. Bluetooth can also be used in IoT devices that require low electricity and operate in a star topology because it is a short-range communication technology [9]. Access control is managed by a central node based on multiple accesses with time and frequency divisions [9]. The term IoT has been used by consumers, businesses, and industries since 1999 [48]. In spite of a large number of literatures defining the Internet of Things, its uses and components, the application of this in industrial settings is rarely clarified [48].

The world's two thirds is covered in water with huge potential, but which has been largely untapped. Recently, a number of basic applications, such as oceanographic data accumulation, sea testing, etc [1]. have been proposed to investigate this potential. A sensor network built in the underwater environment can be defined as one with the primary portion of the network embedded underwater. Rather than radio waves, it has discovered the acoustic wave more sustainable. Sensor networks under the ocean's surface are an important step towards unlocking the secrets of an unknown entity and exploring the Ocean. In conventional sensor networks, communication is conducted on the surface. Smart cities have gained in popularity over the past few years. IoT (Internet of Things) is one of the important technologies that can be utilized [2], which is defined as "the infrastructure of the information society" . As we know, we first discussed the Internet of Underwater Things (IoUT) in 2012 [4]. The concept of Internet of Things (IoT) was invented in 1985 [3]. Smart interconnected underwater objects constitute the Internet of Things. Smart objects could be a variety of underwater sensors, autonomous underwater vehicles (AUV), autonomous surface vehicles (ASV), buoys, ships, etc. As shown in Figure 1, the smart objects might include underwater sensors, AUVs, ASVs, buoys, ships, etc. An important part of smart city development is IoUT, a new class of IoT.

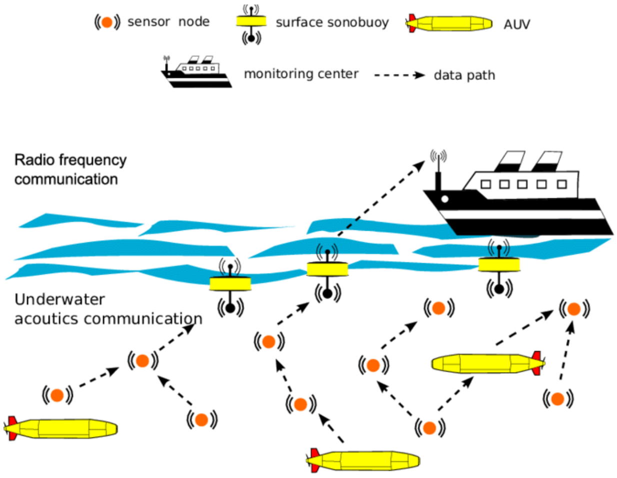

Figure 1. Network architecture of UWSNs.

A growing number of commercial applications use underwater communications [6]. They are often used to monitor the environment, detect disasters and prevent them, collect data for scientific research, map ocean floors, coordinate navigation, etc. [7]. A wide range of autonomous underwater vehicles (AUVs) can be used for underwater applications, each equipped with a wide range of sensors and actuators (environmental, chemical, navigation, etc.). Compared to electromagnetic radio waves, which are commonly used in the air, acoustic waves are the preferred communications medium for underwater communications. Despite their longer propagation distances, low frequency electromagnetic radio waves (30 Hz-300 Hz) require a large antenna and a high transmission power in order to reach their destination. In underwater applications, a moving device makes directional coordination almost impossible. Optical waves have a better propagation rate, but they need directional coordination, which cannot be achieved with underwater waves.

A novel purpose drives the research work. Routers are at the center of fast protocols, and are responsible for revealing paths and maintaining them. Underwater sensor networks researchers have generally been focusing on physical problems, while the routing strategies are relatively new to the network layer, and the most significant task is introducing a strong routing algorithm. Scientists, engineers, and researchers have been working on this over decades, but there are still no optimum protocols that fulfill our requirements and also fulfill our thirst for knowledge. Underwater network protocols are still in their infancy. A brief overview of major routing protocols is provided in our paper, along with the popular routing protocols proposed for UWSNs. A new robust routing algorithm is also introduced as a new feature of UWSN. This protocol will allow UWSN to hang eras. This will benefit people worldwide. In this paper, we review the existing protocol in a brief manner.

2. LITERATURE SURVEY

The protocols created in this article possess motionless possible from various perspectives, despite the fact that a number of authors have submitted quality papers on routing protocol and studies in various fields of UWSNs [10-12]. As well, some authors discussed an analysis of energy efficiency [13-14], formation [15-16], future uses [16-17], the plans for network coding [18], and a wide range of entrance strategies [19]. In Architecture is a must for designing a robust routing protocol we discussed issues related to data transmission, deployment, and location in UWSNs. Models of submerged sensor systems have been discussed in two and three dimensions. In [20], we provide a survey of the existing access control, system and transport layer conventions, as well as discuss open research issues.

Research has been done on a variety of elementary submerged acoustic correspondences. In this paper, submerged channel is described and the researchers mentioned about their two-dimensional and three-dimensional submerged sensor systems. A detailed explanation is provided at all layers of the stack protocol level of the fundamental difficulties for creating effective underwater explanations of networking. In [21], there are also discussions of open research issues and possible outcomes. A technique known as Focused Beam Routing [22] combines the distance-conscious collision prevention protocol that regulates channel access with a geographical routing technique called Focused Beam Routing that relies on nodes knowing only their own locations and final destination locations. A description of UWSN's MAC protocol is provided in [23]. In many protocols [24], collisions can be avoided even when they are distance aware. A variety of protocols is described in [25-29] on energy efficiency and reliability. In some protocols, depth sensors have been recommended for enhancing the possibility of efficient routing in comparatively deeper waters. Depth based routing is one of them, as discussed in [30-31]. There have been several protocols [32-34] that discuss node clustering for sensor nodes. It is also widely discussed that a focused beam routing protocol can provide high quality acoustic communication in [35-36].

3. UWSN ROUTING PROTOCOLS

3.1 Depth Based Routing (DBR)

The DBR protocol illustrates depth functionality in a unique way [32]. The depth sensors are installed in the sensor nodes at different depths. High-resolution sensors calculate depth from the sea surface to the positions they measure, and forward the resulting data packet to comparatively lower-resolution sensors. Deepness information is added to packet headers when sending packets. In this way, data will be sent throughout the network. A protocol like this might not work in deeper water since it's intended for shallow water. On occasion, nodes fail to locate targets with depths lower than their own. When this happens, it transmits packets repeatedly, which can cause congestion. Though taking into account the void problem always to ensure it does not occur. This protocol has the potential to be developed and made feasible in deep water as well.

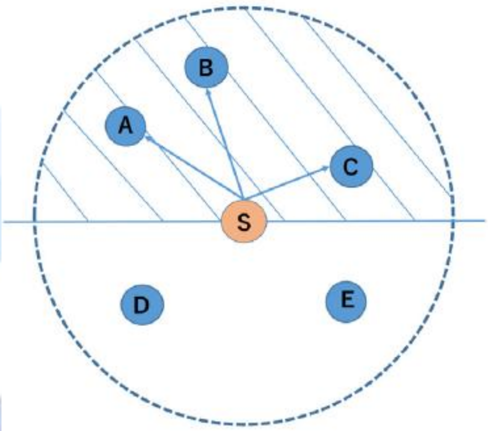

Figure 2. Depth Based Routing

3.2 Distributed Underwater Clustering Scheme (DUCH)

The protocol described in [32] is new and robust. Clusters and phases are included in the protocol. A cluster's organization is the first phase of the project and the operation of the network is the second phase. There are clusters of sensors organized around a cluster head. A local cluster is created in this way for collecting local data. In order to communicate with the sink node, the cluster heads will use multi-hop communication. Operating the network is associated with multiple performance issues. The percentage of energy efficiency rises significantly because of a disciplined data transmission framework. There are some risks associated with this architecture, such as tsunamis, earthquakes, etc. Although it is primarily associated with energy issues.

3.3 Directional Flooding Based Routing (DFR)

DFR's sole purpose is to reduce node count to a minimum. The existing protocols usually focus on transmission reliability but neglect to take into account the quality of the link. In other words, the link quality determines whether the message is sent. Considering link quality as a design consideration, a new protocol has been designed in [37]. An angle between S and D will determine the area in which packets will be transferred. Using this method, all other packets will be delivered to the final sink. To maintain high transmission rates, the angle may be changed with acoustic conditions. Another issue is the problem of voids. When there is a void in the network, at least one node will function. In addition to knowing the location of its own sensor, it also knows where its neighbor is. As a result, the protocol is more effective in comparison to other protocols.

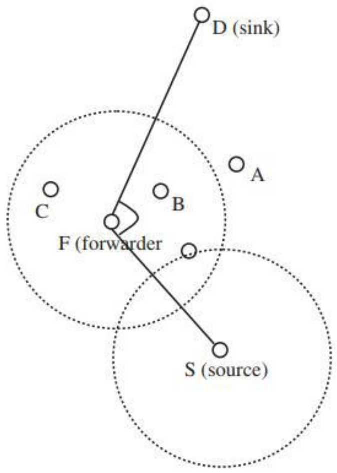

Figure 3. DFR Packet Transmission

3.4 Focused Beam Routing

FBR is described in more detail in [38]. This section explains how FBR differs from other routing paradigms in UWSN.

3.4.1 Delay Tolerant Network (DTN) Routing Protocol

There is an increase in the use of store-carry-forward routing protocols in UWSNs, thus Epidemic Routing (ER), as shown in Figure 4. In this technique, the region of forwarding is determined by the distance between the two communication channels.

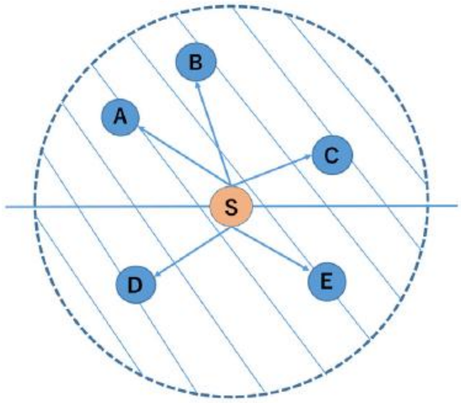

Figure 4. Epidemic

ER protocol produces a large overhead in the network because packets are copied to all possible relay nodes, resulting in battery depletion and reducing the network's lifespan. For UWSN, in many cases, decreasing the overhead is preferred because UWSN nodes have limited storage resources, so increased copies can increase delivery probability in some cases with sparse nodes. In general, however, it is preferable to decrease the overhead when nodes are scarce. Routing protocols have as their primary objective in most UWSN applications the forwarding of data to the modems located at the water surface. By reducing the number of copied packets and requiring nodes to forward packets only to nearby nodes [39,41]], this achieves better performance in these applications.

Additionally, some routing protocols define a relatively small angle in the direction of data collectors, in order to further decrease the overhead and energy consumption, shown in figure 5.

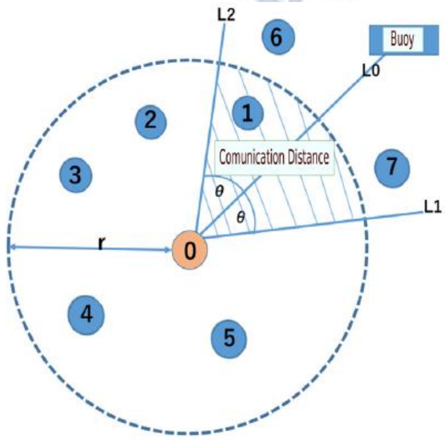

Figure 5.Focused beam

3.4.2 FBR Implementation In ONE Simulator

We were unable to find an open implementation of FBR that could be easily edited and verified in multiple scenarios, even though there are numerous routing protocols proposed and implemented throughout the world. In order to implement FBR, we use One Simulator [41]. In order to simplify the implementation, the assumption they make is as follows.

(a) It is only possible to consider the environment in two dimensions: the width on the horizontal axis and the depth on the vertical axis.

(b) Each node is aware of the location of every other node at any given time, which is actually very hard to achieve in practice without a well-established infrastructure.

(c) The ONE does not possess a single fixed node, because every node is mobile and follows the Random Waypoint Mobility (RWM) model.

(d) The only buoy in our simplified 2D environment has one buoy, which is located in the middle top. All transmissions are aimed at this buoy.

4. APPLICATIONS OF INTERNET OF UNDERWATER THINGS (IoUT)

IoUT applications have been presented in a variety of practical and potential ways over the past decade [42-45].

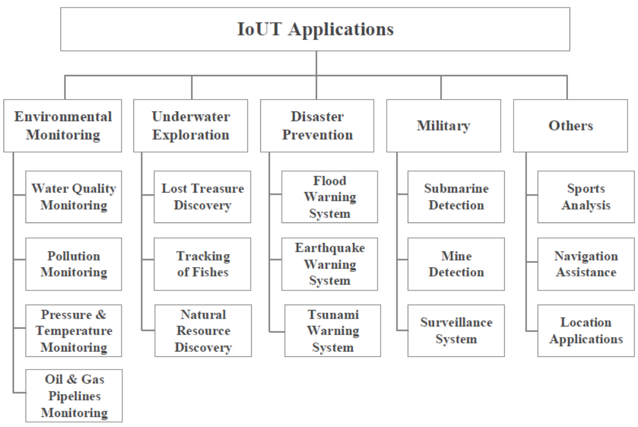

Figure 6. IoUT APPLICATIONS

4.1 Environmental Monitoring

In terms of IoUT applications, environmental monitoring [42] is one of the most commonly used, encompassing water quality monitoring, chemical and biological pollution monitoring, thermal pollution monitoring, pressure and temperature monitoring, and fish tracking. Additionally, UWSNs can be used to monitor oil and gas pipelines.

4.2 Underwater Exploration

Lost treasure can also be discovered using the concept of IoUT [43]. Using autonomous underwater vehicles (AUVs), the Woods Hole Oceanographic Institution discovered the Titanic in 1985. Mineral, metal, coral, and coral reef discovery can also be enhanced by UWSN infrastructure.

4.3 Disaster Prevention

Natural disasters that involve water can be very dangerous. Nuclear disasters such as Fukushima Daiichi (on 11 March 2011) are usually linked to tsunamis after major earthquakes. Floods and earthquakes, especially under water, are expected to be detected by the IoUT and to be managed and prevented [44].

4.4 Military

As a country's military reflects its ability to defend itself, including against underwater attacks, its military is often a reflection of its military strength. Defence requires the use of underwater localization technology, and it can be useful in detecting submarines and submarine mines [45].

4.5 Other Applications

IoUT applications such as navigation and sports are becoming increasingly attractive with the advancement of UWSNs. Think, for instance, about underwater sensors that can be used as reference points for locations, providing valuable information to divers, swimmers, and ships.

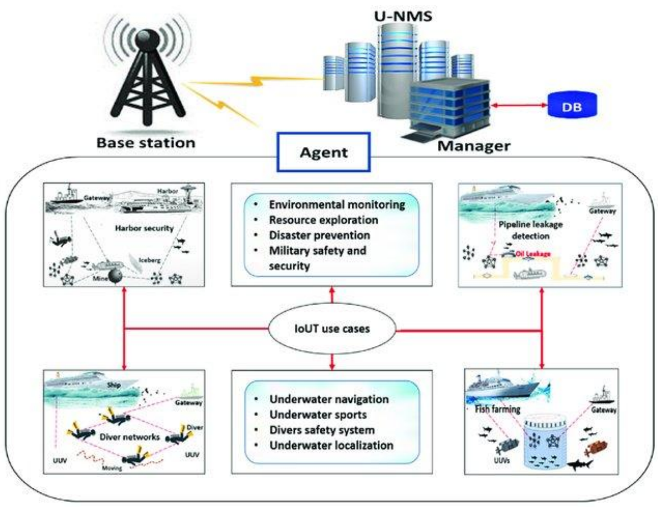

Figure 7. IoUT Use Cases

5. UNDERWATER APPLICATIONS

To simplify data patterns for our simulations [41], we used two main categories of applications.

5.1 Sensor/Location Data

It is typical for these applications to send data from sensor nodes or location information not very frequently towards the data sinks. They can be periodically sent (every few seconds) and are not very large in size (a couple of bytes).

5.2 Control Data

Controlling underwater robots with these applications is intended for complicated tasks. In order to convey the current task status and receive commands from the surface, a node needs to be able to send and receive frequent messages towards the sinks of data. There are no limits on how frequently these messages can be sent (a couple of bytes) and the length depends on how often the messages are sent.

6. SIMULATION RESULTS

The ONE Simulator had already been adapted to implement the ER protocol and to implement store-and-carry forward. For DTN applications, FBR is measured based on four parameters: delivery probability, average number of hops, overhead ratio, and buffer occupancy. The figures 8-10 below illustrate simulation results for delivery probability, average hop count, and overhead ratio for different data patterns and angles of FBR. Every evaluation parameter is simulated ten times, and the average value is shown for each setup. We expect to minimize hop counts and overhead ratios by decreasing the FBR-angle, while maintaining delivery probability at optimal levels. As a result, our network functionality will be acceptable, while general energy consumption will be reduced. The FBR-angle does not appear to significantly affect delivery probability. For both data patterns, the rates of deliveries are similar. We see that, despite the unchanged delivery probability, both hop count and overhead ratio decrease as FBR angle decreases. The overhead ratio for FBR-45 is the most minimal. For each original message, delivery probability shows how many messages were delivered. From the time a message was created at the source node, up to the time it reached its destination, the average hop count shows the average number of times that each message was forwarded. The overhead ratio indicates how many messages are created (copied) for each delivered message.

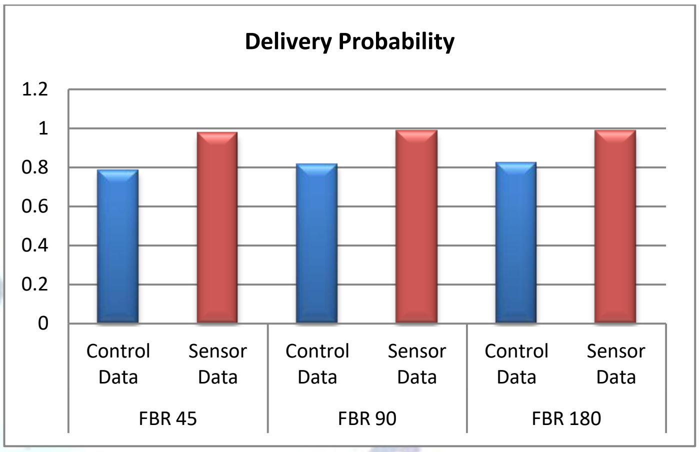

Figure 8. Delivery Probability

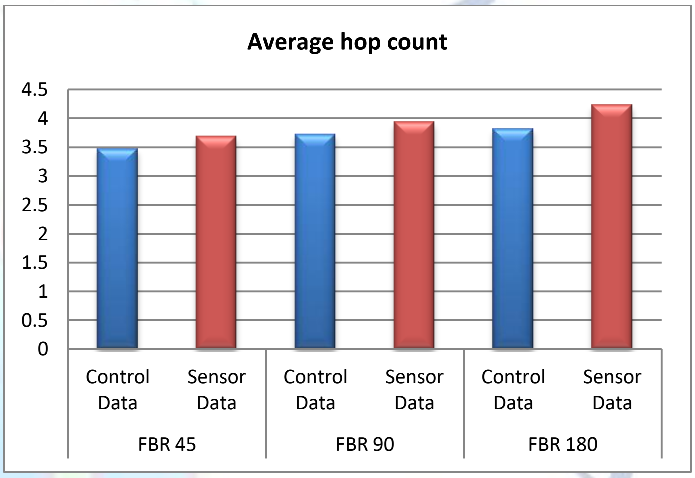

Figure 9. Average hop count

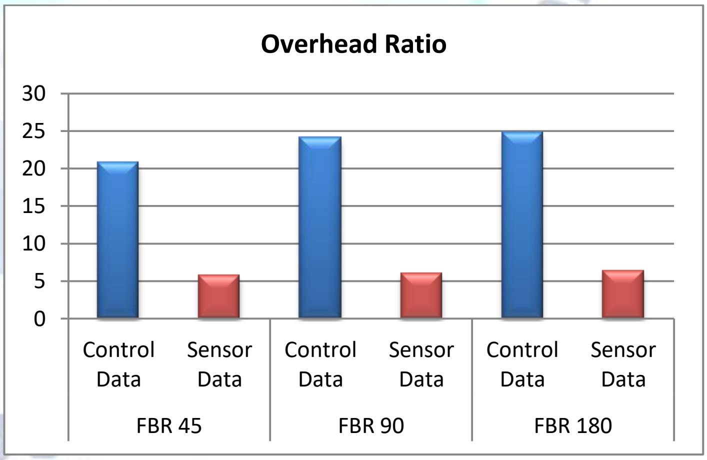

Figure 10. Overhead Ratio

7. CONCLUSION

Routing is an important consideration in terrestrial as well as underwater networks. This paper provides some basic information on underwater sensor networks. Underwater networks require a routing system because the performance of every parameter is somehow related to the routing protocol. This paper presents a rigorous analysis of routing protocols for UWSNs. We are analyzing anxiously the routing protocol that has a relationship to our protocol, and as a result weighing the advantages and disadvantages. An Internet of Underwater Things is described in this paper. Various IoT applications are used in this paper to describe data traffic patterns. In addition, we examined the performance of different FBR angles and different data patterns. ONE Simulator was used to simulate the simulations, and their performance was compared to that of the ER protocol, a well-known routing protocol for DTN. To analyze node behavior when buffers are full, we plan to analyze the node's behavior in the future. The performance of FBR and other routing protocols will be affected as a result of full buffer.

REFERENCES

[1] Utpal Chandra Das, Md. Zahirul Islam, Tanmay Malaker, " DIRECTIONAL VECTOR FORWARD FOCUSED BEAM ROUTING PROTOCOL FOR UNDERWATER SENSOR NETWORK", International Journal of Engineering, Science and Mathematics, Vol. 8 Issue 6, June 2019, pp.114-125.

[2] ITU-T IoT-GSI. Internet of Things Global Standards Initiative. Available online: http://www.itu.int/en/ITU-T/gsi/iot/Pages/default.aspx (accessed on 21 June 2017).

[3] Sharma, C. Correcting the IoT History. Available online: http://www.chetansharma.com/correcting-the-iothistory/ (accessed on 21 June 2017).

[4] Domingo, M.C. An overview of the internet of underwater things. J. Netw. Comput. Appl. 2012, 35, 1879–1890.

[5] Karthik Kumar Vaigandla , Radha Krishna Karne , Allanki Sanyasi Rao, "A Study on IoT Technologies, Standards and Protocols", IBM RD's Journal of Management & Research Volume 10, Issue 2, September 2021, Print ISSN : 2277-7830, Online ISSN: 2348- 5922, pp. 7-14, DOI: 10.17697/ibmrd/2021/v10i2/166798

[6] J. Potter, J. Alves, D. Green, G. Zappa, I. Nissen, K. McCoy, The JANUS underwater communications standard, in: 2014 Underwater Communications and Networking (UComms), Sestri Levante, 2014, pp. 1–4.

[7] Milica. Stojanovic, Underwater acoustic communication, Wiley Encyclopedia of Electrical and Electronics Engineering (1999) http://dx.doi.org/10.1002/047134608X.W5411.

[8] Karthik Kumar Vaigandla, Shivakrishna Telu, Sandeep Manikyala, Bharath Kumar Polasa, Chelpuri Raju, " SMART AND SAFE HOME USING ARDUINO", International Journal of Innovative Research in Technology, Volume 8, Issue 7, December 2021, pp.132-138

[9] Karthik Kumar Vaigandla , Dr.N.Venu, "A Survey on Future Generation Wireless Communications -5G : Multiple Access Techniques, Physical Layer Security, Beamforming Approach", Journal of Information and Computational Science, Volume 11, Issue 9, 2021, pp.449-474

[10] Li, N.; Martinez, J.F.; Chaus, J.M.M.; Eckert, M. A survey on underwater acoustic sensor network routing protocols. Sensors 2016, 16, 414.

[11] Han, G.; Jiang, J.; Bao, N.; Guizani, M. Routing protocols for underwater wireless sensor networks. IEEE Commun. Mag. 2015, 53, 72–78.

[12] Coutinho, R.W.L.; Boukerche, A.; Vieira, L.F.M.; Loureiro, A.A.F. Underwater wireless sensor networks: A new challenge for topology control-based systems. ACM Comput. Surv. 2018, 51, 19–34.

[13] Addisalem, M. COMPARATIVE ANALYSIS OF ROUTING PROTOCOLS FOR UNDER WATER WIRELESS SENSOR NETWORKS: A SURVEY.

[14] Domingo, M. C., & Prior, R. (2008). Energy analysis of routing protocols for underwater wireless sensor networks. Computer communications, 31(6), 1227-1238.

[15] Pompili, D., &Akyildiz, I. F. (2009). Overview of networking protocols for underwater wireless communications. IEEE Communications Magazine, 47(1), 97-102.

[16] Heidemann, J., Ye, W., Wills, J., Syed, A., & Li, Y. (2006, April). Research challenges and applications for underwater sensor networking. In Wireless Communications and Networking Conference, 2006. WCNC 2006. IEEE (Vol. 1, pp. 228-235). IEEE.

[17] Jiejun K, et al. Building underwater ad-hoc networks and sensor networks for large scale real-time aquatic applications. In: Proceedings of the IEEE military communications conference, MILCOM; 2005.

[18] Lucani, D. E., Médard, M., & Stojanovic, M. (2007, September). Network coding schemes for underwater networks: the benefits of implicit acknowledgement. In Proceedings of the second workshop on Underwater networks (pp. 25-32). ACM.

[19] Casari, P., Nati, M., Petrioli, C., &Zorzi, M. (2007, June). Efficient non-planar routing around dead ends in sparse topologies using random forwarding. In Communications, 2007. ICC'07. IEEE International Conference on (pp. 3122-3129). IEEE.

[20] Akyildiz, I. F., &Stuntebeck, E. P. (2006). Wireless underground sensor networks: Research challenges. Ad Hoc Networks, 4(6), 669-686.

[21] Kaur, T. (2018). Underwater Wireless Sensor Networks Challenges: A Review. American Journal of Computer Engineering,

[22] Jornet, J. M., Stojanovic, M., &Zorzi, M. (2010). On joint frequency and power allocation in a cross-layer protocol for underwater acoustic networks. IEEE Journal of Oceanic Engineering, 35(4), 936-947.

[23] Molins, M. &Stojanovic, M. 2006 Slotted FAMA: a MAC protocol for underwater acoustic networks. In Proceedings of the IEEE oceans conference, pp. 1–7. IEEE. (doi:10.1109/OCEANSAP.2006.4393832)

[24] Peleato, B., &Stojanovic, M. (2007). Distance aware collision avoidance protocol for ad-hoc underwater acoustic sensor networks. IEEE Communications Letters, 11(12).

[25] Chen, J., Wu, X., & Chen, G. (2008, October). REBAR: a reliable and energy balanced routing algorithm for UWSNs. In Grid and Cooperative Computing, 2008. GCC'08. Seventh International Conference on (pp. 349-355). IEEE.

[26] Zenia, N. Z., Aseeri, M., Ahmed, M. R., Chowdhury, Z. I., & Kaiser, M. S. (2016). Energy-efficiency and reliability in MAC and routing protocols for underwater wireless sensor network: A survey. Journal of Network and Computer Applications, 71, 72-85.

[27] Ahmed, S., Javaid, N., Khan, F. A., Durrani, M. Y., Ali, A., Shaukat, A., ... &Qasim, U. (2015). Co-UWSN: Cooperative energy-efficient protocol for underwater WSNs. International Journal of Distributed Sensor Networks, 11(4), 891410.

[28] Xie, P., & Cui, J. H. (2007, August). R-MAC: An energy-efficient MAC protocol for underwater sensor networks. In International Conference on Wireless Algorithms, Systems and Applications (WASA 2007) (pp. 187-198). IEEE.

[29] Wahid, A., Lee, S., & Kim, D. (2011, June). An energy-efficient routing protocol for UWSNs using physical distance and residual energy. In OCEANS, 2011 IEEE-Spain (pp. 1-6). IEEE.

[30] Yan, H., Shi, Z. J., & Cui, J. H. (2008, May). DBR: depth-based routing for underwater sensor networks. In International conference on research in networking (pp. 72-86). Springer, Berlin, Heidelberg.

[31] Guangzhong, L., &Zhibin, L. (2010, May). Depth-based multi-hop routing protocol for underwater sensor network. In Industrial Mechatronics and Automation (ICIMA), 2010 2nd International Conference on (Vol. 2, pp. 268-270). IEEE.

[32] Domingo, M. C., & Prior, R. (2007, September). A distributed clustering scheme for underwater wireless sensor networks. In Personal, Indoor and Mobile Radio Communications, 2007. PIMRC 2007. IEEE 18th International Symposium on (pp. 1-5). IEEE.

[33] Yang, G., Xiao, M., Cheng, E., & Zhang, J. (2010, April). A cluster-head selection scheme for underwater acoustic sensor networks. In Communications and Mobile Computing (CMC), 2010 International Conference on (Vol. 3, pp. 188-191). IEEE.

[34] Wang, P., Li, C., & Zheng, J. (2007, June). Distributed minimum-cost clustering protocol for underwater sensor networks (UWSNs). In Communications, 2007. ICC'07. IEEE International Conference on (pp. 3510-3515). IEEE.

[35] Jornet, J. M., Stojanovic, M., &Zorzi, M. (2008, September). Focused beam routing protocol for underwater acoustic networks. In Proceedings of the third ACM international workshop on Underwater Networks (pp. 75-82). ACM.

[36] Montana, J. M., Stojanovic, M., &Zorzi, M. (2008, September). Focused beam routing protocol for underwater acoustic networks. In Proc. of ACM International Workshop on Underwater Networks (WUWNet), San Francisco, CA.

[37] Daeyoup, and Dongkyun Kim. "DFR: Directional flooding-based routing protocol for underwater sensor networks." OCEANS 2008. IEEE, 2008.

[38] Josep Miquel Jornet, Milica Stojanovic, Michele Zorzi, Focused beam routing protocol for underwater acoustic networks, in: In Proceedings of the Third ACM International Workshop on Underwater Networks (WuWNeT '08), Association for Computing Machinery, New York, NY, USA, pp. 75–82.

[39] G. Qiang, T. Shigeyasu, Ch. Chen, A new DTN routing strategies ensuring high message delivery ratio while keeping low power consumption, Internet of Things 17 (2022) http://dx.doi.org/10.1016/j.iot.2021.100463.

[40] R. Thangarajan, T. Siva, R. Boopalachakaravarthy, Adaptive energy efficient routing protocol with extended lifetime in underwater sensor networks, in: 2013 International Conference on Communication Systems and Network Technologies, 2013, pp. 322–326, http://dx.doi.org/10.1109/CSNT.2013.74.

[41] E. Kulla, K. Matsuo, L. Barolli, Evaluation of Focused Beam Routing Protocol for Different Applications of Underwater Sensor Networks, Advances on Broad-Band Wireless Computing, Communication and Applications, Springer International Publishing, ISBN: 978-3-030-90072-4, 2021, pp. 37–45.

[42] E. Felemban, F. K. Shaikh, U. M. Qureshi, A. A. Sheikh, and S. B. Qaisar, "Underwater sensor network applications", International Journal of Distributed Sensor Networks, 2015.

[43] A. Davis, and H. Chang, "Underwater wireless sensor networks", IEEE Oceans, 2012.

[44] R. M. Perez, J. G. Pintado, and A. S. Gómez, "A realtime measurement system for long-life flood monitoring and warning applications", Sensors, vol. 12, no. 4, 2012.

[45] S. Khaledi, H. Mann, J. Perkovich, and S. Zayed, "Design of an underwater mine detection system", IEEE Systems and Information Engineering Design Symposium (SIEDS), 2014.

[46] Chien-Chi Kao, Yi-Shan Lin, Geng-De Wu and Chun-Ju Huang, " A Comprehensive Study on the Internet of Underwater Things: Applications, Challenges, and Channel Models", Sensors 2017, 17, 1477; doi:10.3390/s17071477

[47] Chien-Chi Kao, Yi-Shan Lin, Geng-De Wu, Chun-Ju Huang, " A Study of Applications, Challenges, and Channel Models on the Internet of Underwater Things ", Proceedings of the 2017 IEEE International Conference on Applied System Innovation, IEEE-ICASI 2017 - Meen, Prior & Lam (Eds), ISBN 978-1-5090-4897-7, pp.1375-1378.

[48] Nagaraju Bompelli, Ramadevi Manchala and RadhaKrishna Karne, "IOT BASED SMART SENSOR SOC ARCHITECTURE FOR THE INDUSTRIAL INTERNET OF THINGS", The International journal of analytical and experimental modal analysis, Volume XII, Issue X, October/2020, Page No:491-496.