International Journal on Emerging Technologies **11**(3): 164-168(2020)

ISSN No. (Print): 0975-8364
ISSN No. (Online): 2249-3255

Design of a Fault Detection and Recovery method for Cluster based Underwater Wireless Sensor Networks

Tejaswini R. Murgod[1] and S. Meenakshi Sundaram[2]
[1]Assistant Professor, Department of Computer Science and Engineering, Mysuru (Karnataka), India.
[2]Professor, Department of Computer Science and Engineering, Mysuru, (Karnataka), India.

(Corresponding author: Tejaswini R. Murgod)
(Received 27 January 2020, Revised 24 March 2020, Accepted 27 March 2020)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: In the past few years Underwater Wireless Sensor Networks (UWSN) has achieved a tremendous area of interest in research. Large number of sensor nodes operates independently in harsh underwater environment. Failures and faults are inevitable in UWSN because of high water pressure, high node mobility ratio, low bandwidth etc. The network operation and data communication will cause the sensor nodes to dissipate their energy at a faster rate. As replacing the underwater sensor nodes is a challenging task, it's not easy to recharge the batteries of the nodes when energy is dissipated. Failure of nodes may cause data loss and connectivity loss. Therefore it is necessary to identify such faults and failures within the network and propose some mechanism to overcome such problems.

In this research work we propose a Cluster Based Fault Detection and Recovery method to identify the occurrence of fault within the CH. We observe that this method proves it is fast and efficient solution for robust and scalable UWSN. The proposed algorithm is compared with other methodologies like RCH and SDMCGC. The simulation results show that in proposed methodology delay is reduced by 10% to 15%, Packet Delivery Ratio is increased by 5% and 15%, and Packet Drop Ratio is reduced by 10% to 24%. In this research work we also apply fault detection and recovery method to the ECBLA, algorithm proposed by us prior to this research. We observe that the average location error is reduced by 1.74566m.

Keywords: Underwater Communication; Underwater Wireless Sensor Networks (UWSN), Cluster Based Fault Detection and Recovery method, Packet Delivery Ratio, Average Location Error, Packet Drop Ratio.

I. INTRODUCTION

Underwater wireless sensor networks (UWSN) are deployed in various applications such as disaster monitoring, pollution monitoring, military applications etc. These applications utilize large number of sensor nodes to measure the parameters of interest. These nodes have limited battery power and drift continuously with water, so it is very difficult to replace the batteries of the sensor nodes. Nodes underwater may be affected by external environment and some malfunctioning within the node itself [1, 2].

Faults are inevitable, so faulty sensor nodes may cause the network failure which may affect the economy of the concerned application and reduce the accuracy of sensed data. Hence identifying the faults in UWSN is an important task that needs to be addressed. Identifying faults may also result in increase in reliability, connectivity of the network and increases the accuracy of the sensed data [3].

Faults can occur in the hardware part of the devices and are called as hard faults. Hard faults mean complete damage of the hardware devices or nodes which results in communication failure between the nodes. Faults that occur in software applications are called as soft faults. Soft faults results in erroneous calculation on data, node malfunctioning during session, nodes unable to process sensed data etc.

Based on the time and severity of the faults they can be classified as temporary, intermittent and permanent faults. Permanent faults are those faults that cannot be recovered easily, like node failure, failure of some hardware component etc. To recover permanent faults, the devices must be completely replaced. Intermittent faults are those that occur in a specific pattern at some intervals. These can occur due to unstable behavior of some hardware components or because of errors in some program subsets. Temporary faults are those that occur due to some temporary environment factors like change in temperature, salinity of water, temporary disturbance in communication link, noise etc.

Many localization algorithms are proposed but very few provide the recovery mechanism. The fault detection methods studied earlier includes high delay and low packet delivery ratio which is reduced by our proposed methodology [4-6].

In this research work we propose a methodology for identifying the faults and recovery measure within the UWSN. The major contribution of our work can be summarized as below.

– We propose a fault detection algorithm which identifies the occurrence of fault of CH node.

– We propose a recovery technique of the faulty CH node.

– We perform extensive simulations of the proposed algorithm and compare results with an existing algorithm for performance measurement.

The organization of the paper is as follows section II presents the related work. In section III we specify the system model of our proposed methodology. Section IV discusses the Fault Detection and Recovery algorithm. In section V we highlight the simulation results and compare the performance with existing work. Conclusion and summary of research work are presented in section VI.

II. RELATED WORK

Failures are inevitable in sensor networks due to inhospitable environment and unattended deployment. Failures arise because of energy loss in the nodes, climatic changes, hardware errors etc. cluster based fault detection and recovery method provides quick and efficient solution for robust networks. Clustered based approach for fault detection also consumes less energy when compared to other techniques [7].

An efficient error recovery scheme using network coding and multipath routing is discussed in [8]. As underwater sensor nodes are larger nodes with high computation capability than terrestrial node, network coding can be an efficient method for fault detection in UWSN. Network coding requires multiple paths from source to destination.

In the clustered approach as we know Cluster Head (CH) plays an important role. It's through the CH only all the members of the cluster can communicate. CH maintains the information of all the nodes within the cluster; it also collects the sensed data from cluster members and forwards it to the base station. As CH node plays a crucial part in clustered approach, failure of CH may result in serious issues. Ovaliadis *et al*., (2014) proposes a fault detection and recovery method for CH nodes in UWSN [9].

Wang *et al.,* (2007) proposes an agreement based fault detection for UWSN. The proposed methodology aims to accurately detect the node failure in order to reduce the energy utilization in case of false fault detection. To reduce the false fault detection the methodology allows each cluster member to independently detect the fault in CH and then come up with an agreement with the other cluster members. The authors also claim that the proposed methodology can detect fault accurately even when the packet loss ratio is high [10].

Venkataraman *et al.,* (2007) proposes a fault detection and recovery method where each node maintains a table of information related to balance energy. Once the node identifies that its energy level is decreasing than the defined threshold than it immediately sends a failure packet to its parent node and immediate child node. This method saves the energy utilization of the nodes as all the nodes within the cluster do not participate in fault detection. It is the responsibility of the parent and immediate child node to take up the recovery process and bridge the gap occurred due to failed faulty node. Through simulation the author specifies that this is methodology is energy efficient and consumes less time for recovering. Proposed methodology saves almost 75% to 80% of the energy [11].

Asim *et al*., (2009) proposes and cellular approach for fault detection and recovery. Grid based architecture is proposed where fault detection is across the cells. Each cell is constituted with group of nodes and it is the responsibility of the cell manager and secondary manager to identify the faults. The structure of the cell is not modified while dealing with the energy drained nodes [12].

Jia *et al.,* (2018) proposes an algorithm to detect transient faults. The data collected within short duration will be almost similar, if there is change in data than it is assumed that it is because of fault in the system. The algorithm collects al the historical data sensed by the node. The node is considered as normal if there is no variation in data collected during short span; if there is variation then it is considered as faulty node. The proposed algorithm consumes less energy and reduces the detection errors [13].

Cheng *et al*., (2018) proposes a vector regression based fault detection model which reduces false fault diagnosis. The proposed algorithm combines fault diagnosis and neighbor coordination which eliminates the influence of faulty node. All the sensor nodes are randomly placed and have a same communication range. Nodes can communicate by one hop or by multi hop with their neighbors. Every node periodically broadcast the sensed data as temperature, wind speed, air pressure etc. At timestamp t the nodes apply the fault detection algorithm to detect the faults. The simulation results depicts that the proposed algorithm fault detection is around 13% and it also reduces false fault alarms [14].

Du *et al*., (2012) proposes and application oriented fault detection and recovery model where nodes self restore the connectivity when failure occurs in order to reduce the node movement and message overhead. Each node first identifies whether it is a critical node, if it is a critical node it immediately identifies a neighbor node as its backup. Once the backup node identifies the failure of the critical node it takes certain measures to replace the faulty node. The main goal of the algorithm is to reduce the node mobility and communication overhead [15].

III. SYSTEM MODEL

The network model of the proposed system is similar to our previous work EECBLA. Here n numbers of sensor nodes are deployed deep inside the sea. These sensor nodes are used to sense the information and forward it to the anchor nodes. Anchor nodes are high power GPS enabled nodes who can estimate their location on their own. These anchor nodes and surface buoys help the sensor nodes to locate themselves. Without the help of the anchor nodes it is very difficult for the sensor nodes to locate themselves. Besides helping the sensor node to localize themselves anchor nodes also collect the sensed information from these sensor nodes and forwards it to the surface buoys, which inturn forwards it to the base station where processing of the sensed information takes place. EECBLA is a cluster based approach where the anchor nodes play a role of the Cluster Head (CH) and all other sensor nodes are Cluster Members (CM). Fig. 1 depicts the system architecture.

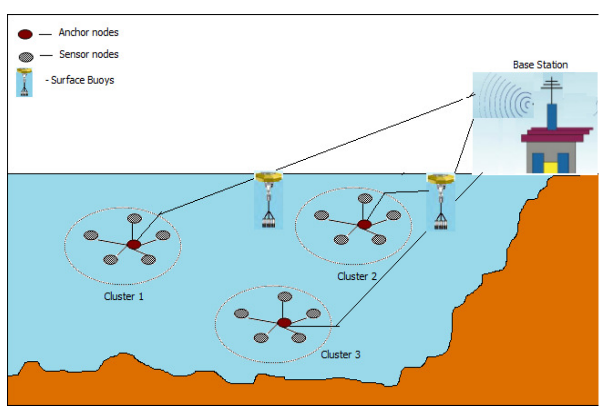

Fig. 1. System Architecture.

IV. PROPOSED SYSTEM

As the sensor nodes are mobile and continuously drift with the water pressure. It is important to estimate the location information of the sensor nodes periodically. Anchor nodes play an important role in localizing the sensor nodes. If the anchor node is faulty or it fails then it is very difficult for the sensor node to locate themselves and the senses information will also not reach the base station for processing because sensed information is aggregated at anchor node and then forwarded to the surface buoys.

The surface buoys are located at the surface so they can be easily replaced or recharged if there is a failure. But anchor nodes are inside the sea so it is bit difficult to easily replace them when a fault is identified. So in this paper we propose a recovery method for the anchor nodes in case if any fault or failure occurs in the system.

There are two types of faults permanent and temporary faults. Permanent fault means node failure, link failure, hardware component malfunctioning etc. Temporary fault is the fault which is recovered within short span like packet loss due to congestion, signal attenuation, error occurred due to temperature changes underwater or error due to increase in water pressure etc.

In this proposed system we try to identify the faults in the anchor nodes and provide a recovery method if the failure of anchor node is identified. Anchor nodes are active all the time and periodically keep on helping sensor nodes to localize themselves, sensor node work in active and sleep mode for minimum utilization of their energy. But as anchor node are active all the time their energy dissipation is higher.

A. Fault Detection Algorithm

Initially we identify the occurrence of fault and then provide a recovery measure. Anchor nodes act as a CH. Here we designate another high power GPS enabled node as Alternate CH (ACH) whose job is to identify the fault in CH and then provide recovery measure. The CH periodically sends a message to the ACH which provides the information related to the status of the CH. ACH will be in inactive state and will just listens to all the messages sent by CH and maintains it in a table. Periodically CH sends a message to the ACH as depicted in Fig. 2.

Message Id (MID)	Cluster Head ID (CHID)	CH node density	Residual Energy (RE)	Load	Link Quality	Timestamp	TTL

Fig. 2. Packet format of CH message to ACH.

The message consists of Message ID (MID) which is the unique identification for every message generated, CHID which is the unique identification of each CH, CH node density, Residual Energy (RE) of the CH, Load of the CH, Link Quality, Timestamp which is the time at which the message was sent and TTL which specifies the maximum TTL value.

Upon receiving the message from CH the ACH maintains the received information in the table called CH table and keep on monitoring the CH node. When it identifies that there is an occurrence of the fault then it initiates the recovery method. As we know fault can arise due to node failure or due to the link failure. The ACH continuously monitors the RE and the load of the CH, when it identifies that residual energy or the load of the CH is beyond the defined threshold then it assumes that there are chances of CH node failure and immediately starts with the recovery process.

Fault can also occur in the system due to link failure. The ACH continuously monitors the link quality of the CH and Timestamp. If the message sent by CH is lost in between because of poor link quality that is identified by the ACH and immediately initializes the recovery process.

After every t intervals ACH receives a message from CH, if ACH did not receive any message during the interval than it assumes that message might be lost due to some noise and waits for successive 2 t intervals. By the end of 2t intervals also ACH did not receive any message from CH then ACH identifies the fault and initiates the recovery method. The algorithm for fault detection is depicted below.

B. Algorithm for Fault Detection

1. for CH nodes € {1,2,……., C} Clusters
2. After every time interval t CH send a message to ACH
3. ACH continuously waits for the message from CH.
4. Upon receiving the message
5. if RE or load > Threshold
6. Then initiates recovery method
7. Else
8. makes an entry in the CH table and sleep until next interval
9. End if
10. if message is not received for 2 successive t intervals
11. then initiates recovery method.
12. End if
13. End for.

C. Recovery method

Upon identifying the fault in the CH, ACH immediately initiates the recovery method. In the recovery method ACH collects the backup data and identifies the entire CM belonging to the cluster. It then broadcast a message to all the CM of the cluster that the CH has failed and announces itself as the new CH. Fig. 3 depicts the packet format of the broadcast message.

Message ID (MID)	ACH ID	Timestamp	TTL

Fig. 3. Packet format of ACH message to CM.

D. Algorithm for Fault Recovery

1. ACH identifies all the CM within the cluster
2. Takes the backup data from the CH
3. ACH initializes itself as new CH
4. Broadcast the message regarding new CH to all CM
5. Continue functioning as CH of the cluster.

V. SIMULATION AND RESULT DISCUSSON

For simulation the nodes are randomly deployed to form the cluster within the network. The network setting and performance evaluation are discussed in this section.

A. Environment settings
The environment settings used for simulation are provided in Table 1.

Table 1: Simulation Parameters.

Parameters	Value
Network Area	100m * 100m
No of nodes	50 nodes per cluster
Simulation Time	500 s
Channel	Underwater Channel
Sensor node initial energy	10 kJ
Transmission power	2.8 w
Channel bandwidth	10 kHz
Packet Size	50, 100, 150, 200 bytes

Around 50 nodes per cluster are placed randomly within the network area of 100m * 100m. The simulation is run for 500 sec, sensor node initial energy is set to 10kJ, channel bandwidth is 10 kHz and packet size is set to 50, 100, 150 and 200 bytes respectively.

B. Performance Comparison
The main objective of the proposed methodology is fault detection and recovery of the CH nodes. The fault detection methodology is applied to our previous algorithm EECBLA and comparison is done.
Initially the performance of fault detection mechanism is compared with other protocols like RCH, SDMCGC with respect to packet delivery ratio, average delay, and packet drop and then we compare the performance of EECBLA with fault detection and without fault detection and recovery mechanism.

Table 2: Comparison Table of End to End Delay versus Number of Faulty nodes.

No. of Faulty Nodes	Delay (secs)		
	FDR	RCH	SDMCGC
1	0.045	0.065	0.05
2	0.046	0.07	0.052
3	0.05	0.072	0.054
4	0.051	0.075	0.055
5	0.052	0.08	0.058

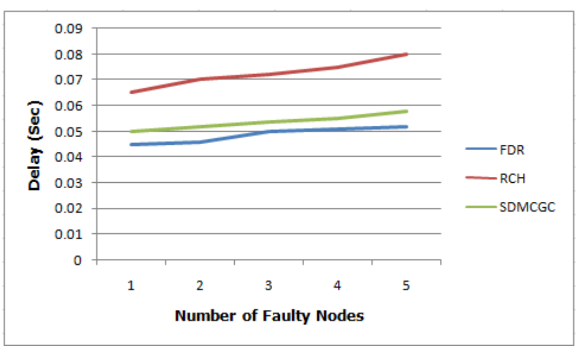

Fig. 4. End to End Delay versus Number of Faulty nodes.

The Fig. 4 shows the comparison of end to end delay versus number of faulty node. As the number of faulty nodes increases in the network the delay also increase. This is because of more time is consumed for detection and recovery. The proposed methodology Fault Detection and Recovery (FDR) has less delay when compared to RCH and SDMCGC. When compared to SDMCGC and RCH the average delay is reduced by 10% to 15%.

Table 3: Comparison Table of Packet Delivery Ratio versus Number of Faulty nodes.

No. of Faulty Nodes	Packet Delivery Ratio (secs)		
	FDR	RCH	SDMCGC
1	0.028	0.025	0.015
2	0.026	0.0232	0.014
3	0.0268	0.0234	0.0145
4	0.0265	0.0236	0.0142
5	0.026	0.0239	0.014

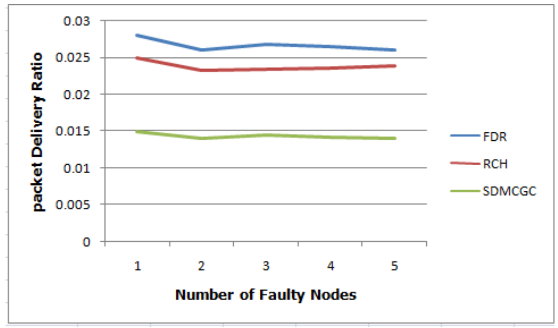

Fig. 5. Packet Delivery Ratio versus Number of Faulty nodes.

Packet Delivery ration is the ratio of number of packet transmitted by the number of packets received successfully. High packet delivery ratio results in higher accuracy. Fig. 5 depicts the comparison of Packet Delivery Ratio by the Number of faulty nodes. The comparison shows that FDR has better delivery ratio when compared with RCH and SDMCGC. FDR outperforms RCH by 5% and SDMCGC by 15%.

Table 4: Comparison Table of Number of Packets Dropped versus Number of Faulty nodes.

No. of Faulty Nodes	Number of Packets Dropped		
	FDR	RCH	SDMCGC
1	16	18	22
2	16.5	18.5	22.5
3	17	18.7	22.6
4	17.2	18.9	23
5	17.6	19	23.2

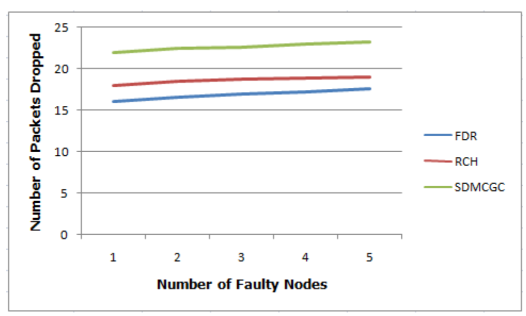

Fig. 6. Number of Packets Dropped versus Number of Faulty nodes.

Packet drop is the number of packets dropped during transmission. As the number of faulty nodes increases the packet drop also increase. The Fig. 6 depicts this comparison. The graph specifies that FDR packet drop ratio is 24% less compared to SDMCGC and by 10% less when compared with RCH.

Table 5: Comparison Table EECBLA with and without Fault Detection.

No. of Iterations	Localization Error	
	EECBLA with Fault Detection	EECBLA without Fault Detection
1	3.0126	4.0604
2	3.4256	5.8304
3	3.2562	4.815
4	3.5623	6.0014
5	3.9823	5.2601

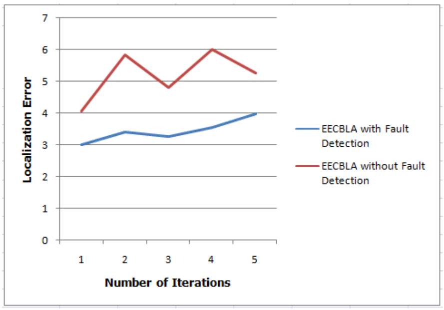

Fig. 7. EECBLA with and without Fault Detection.

EECBLA is our previous work where we propose a localization algorithm. EECBLA does not incorporate fault detection. Hence as a future enhancement we apply the fault detection and recovery methodology proposed in this paper to EECBLA and compares the performance. EECBLA was run for 5 iterations and the average localization error was 5.19346m. In order to reduce the localization error in EECBLA we implement EECBLA with fault detection and recovery method. The average localization error achieved by EECBLA with fault detection and recovery method is 3.4478m. The Fig. 7 shows comparison of the performance of EECBLA with fault detection and without fault detection. We can analyze from the graph that the average localization error is reduced by 1.74556m by incorporating fault detection and recovery methodology.

VI. CONCLUSION

In this paper we proposed a fault detection and recovery method for cluster based underwater communication. The main objective is to identify the faulty CH and provide a recovery measure. The proposed methodology is applied to EECBLA and also comparison with other fault detection algorithms is done. Here anchor nodes act as the CH, as CH plays an important role in clustered based communication we provide recovery measure to the faulty CH node. An ACH continuously monitors the activities of the CH, when it identifies that the CH residual energy or the load of the CH is greater than the defined threshold it immediately initiates the recovery process.

The proposed methodology is compared with RCH and SDMCGC. The simulation results proves that proposed methodology performs better than existing system in terms of end to end delay, packet delivery ration and number of packet dropped. The end to end delay is reduced by 10% to 15%, Packet Delivery Ratio is increased by 5% and 15%, and packet drop ratio is reduced by 10% and 24%.

In order to reduce the localization error in EECBLA we incorporate fault detection and recovery method. The simulation results prove that the average location error is reduced by 1.74556m.

REFERENCES

[1]. Asim, M., Mokhtar, H., & Merabti, M. (2008). A fault management architecture for wireless sensor network. In *2008 International Wireless Communications and Mobile Computing Conference,* 779-785.

[2]. Emperuman, M., & Chandrasekaran, S. (2020). Hybrid Continuous Density Hmm-Based Ensemble Neural Networks for Sensor Fault Detection and Classification in Wireless Sensor Network. *Sensors, 20(*3), 1-23.

[3]. Priyadarshini, R. R., & Sivakumar, N. (2020). Failure prediction, detection & recovery algorithms using MCMC in tree-based network topology to improve coverage and connectivity in 3D-UW environment. Applied Acoustics, *158*, 107053.

[4]. Vihman, L., Kruusmaa, M., & Raik, J. (2019). Overview of Fault Tolerant Techniques in Underwater Sensor Networks. arXiv preprint arXiv:1910.00889.

[5]. Yuvaraja, M., & Sabrigiriraj, M. (2017). Fault detection and recovery scheme for routing and lifetime enhancement in WSN. *Wireless Networks, 23*(1), 267-277.

[6]. Nitesh, K., & Jana, P. K. (2016). Distributed fault detection and recovery algorithms in two-tier wireless sensor networks. *International Journal of Communication Networks and Distributed Systems, 16*(3), 281-296.

[7]. Yadollahi, M., & Jalali, S. V. (2010). A survey cluster-based and cellular approach to fault detection and recovery in wireless sensor networks. *World Applied Sciences Journal, 8*(1), 76-85.

[8]. Guo, Z., Wang, B., & Cui, J. H. (2007). Efficient error recovery using network coding in underwater sensor networks. In *International Conference on Research in Networking*, 227-238. Springer, Berlin, Heidelberg.

[9]. Ovaliadis, K., Savage, N., & Tsiantos, V. (2014). A new approach for a better recovery of cluster head nodes in underwater sensor networks. In *2014 International Conference on Telecommunications and Multimedia (TEMU)*, 167-172.

[10]. Wang, P., Zheng, J., & Li, C. (2007). An agreement-based fault detection mechanism for under water sensor networks. In IEEE GLOBECOM 2007-*IEEE Global Telecommunications Conference,* 1195-1200.

[11]. Venkataraman, G., Emmanuel, S., & Thambipillai, S. (2007). A cluster-based approach to fault detection and recovery in wireless sensor networks. In *2007 4th International Symposium on Wireless Communication Systems,* 35-39.

[12]. Asim, M., Mokhtar, H., & Merabti, M. (2009). A cellular approach to fault detection and recovery in wireless sensor networks. In *2009 Third International Conference on Sensor Technologies and Applications*, 352-357.

[13]. Jia, S., Ma, L., & Qin, D. (2018). Fault Detection Modelling and Analysis in a Wireless Sensor Network. *Journal of Sensors,* 1-9.

[14]. Cheng, Y., Liu, Q., Wang, J., Wan, S., & Umer, T. (2018). Distributed Fault Detection for Wireless Sensor Networks Based on Support Vector Regression. *Wireless Communications and Mobile Computing,* 1-8.

[15]. Du, J., Xie, L., Sun, X., & Zheng, R. (2012). Application-oriented fault detection and recovery algorithm for wireless sensor and actor networks. *International Journal of Distributed Sensor Networks*, *8*(10), 273792, 1-9.

How to cite this article: Murgod, T. R. and Sundaram, S. M. (2020). Design of a Fault Detection and Recovery method for Cluster based Underwater Wireless Sensor Networks. *International Journal on Emerging Technologies*, *11*(3): 164–168.