

# Performance Analysis of Energy Efficient and Reliable Protocols for Intra & Inter-Cluster Communications in Wireless Sensor Networks



S. Prakasam, S. Lavanya

**ABSTRACT:** *The discovery and the use of many wireless technologies are paving way for new remote monitoring applications. The sensing devices are becoming popular because of their flexibility, performance, low cost and portability. Wireless Sensor Networks (WSN) is a good alternative to wired systems because of easy deployment in remote areas. Wireless Sensor Networks are used in different domains for various applications because of their salient characteristics like reduced power consumption, scalability, ability to respond immediately within a short span of time, reliability, dynamic in nature, low cost and easy installation. The main objective of this paper work is to find a suitable energy efficient, scalable and reliable communication protocols for intra-cluster and intercluster communication. Therefore the proposed research work follows three different phases. To achieve the desired results, the proposed research work concentrates on three protocols namely Energy Efficient and Reliable Clustering Routing Protocol (EERCRP), Energy Efficient and Reliable MAC Protocol (EERMAC) and Energy Efficient and Reliable Hybrid Transport Protocol (EERHTP). EERCRP and EERMAC are intra-cluster communication protocols that help in cluster formation and effective data sensing. EERHTP is a transport layer protocol that is used for inter-cluster communication. All the above protocols are evaluated using network simulator NS2 for their performance analysis. EERCRP is compared with PASCC and PCDCC which from the root level header node are existing congestion and queue based hybrid clustering protocols. The proposed EERCRP follows hierarchical cluster formation where the leader node is selected based on queue length, residual energy of the node and distance. It is efficient than the existing methods in terms of energy and reliability metrics. EERMAC is compared with existing MAC protocols namely SMAC, IEEE 802.11 EDCA and EA-MAC. SMAC follows traditional TDMA or CSMA method of data access. They are suitable only for periodic data sensing. The proposed EERMAC allows hybrid data sensing consisting of both periodic and event based data which are classified using priority levels. Event based data is assigned higher priority than periodic data. Queues are used for storing both types of data using various levels of threshold values. EERMAC uses CSMA/CA method for event based data. Variable TDMA method is used for event based and periodic data. EERHTP is a transport layer protocol that uses two types of reliability models namely ACK and NACK depending on the type of data. All the three protocols are evaluated both for energy and reliability metrics such as total energy consumption, residual energy comparison, energy consumption per packet, packet delivery ratio, delay, packet drop, jitter, throughput and network routing overhead. Thus it is concluded that all the three protocols are more optimal than the existing protocols and prove to be the best protocols for intracluster and inter-cluster communications.*

**Keywords:** *Clustering; Data priority; Efficiency; Energy; MAC layer; Protocols; Queue; Reliability; Sensor; Networks; Wireless.*

Revised Manuscript Received on May 15, 2020.

\* Correspondence Author

**Dr. S. Prakasam\***, Associate Professor, Department of Computer Science & Applications, Sri Chandrasekharendra Saraswathi Viswa Maha Vidyalaya University, Kanchipuram – 631 561, India

**Dr. S. Lavanya**, Head, Department of Computer Science and Applications, Auxilium College for Women, Vellore, Tamil Nadu, India.

© The Authors. Published by Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP). This is an [open access](https://creativecommons.org/licenses/by-nc-nd/4.0/) article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>)

## I. INTRODUCTION

Reliable data delivery is the prime motivation for any application developed using Wireless Sensor Network (WSN). This objective is mostly achieved by developing a network that is reliable, energy efficient, scalable and achieves the necessary Quality of Service (QoS) requirement. Medium Access Control (MAC) provides easy access of the channel among various sensor nodes in a clustered network in a fair and efficient manner. A MAC protocol plays an important role in energy conservation, reliable packet delivery, avoids latency and provides QoS. The research on MAC protocol design is mainly needed for accurate data delivery [Jalel Ben-]. Routing protocols are classified basically as flat routing, routing based on geographical location of nodes and hierarchical routing. In flat routing, almost all nodes play the same role. Flat routing protocols are further classified as Proactive, Reactive and Hybrid protocols. Commonly used proactive protocols include DSDV, GSR, OLSR, CGSR and WRP. AODV, DSR, TORA, ABR and SMR are some of the reactive protocols (Vergados). Communication is the major consumption of energy. As energy preservation is the main design criteria of the MAC protocols, a number of energy saving mechanisms are proposed in the literature. The main design objective of all energy saving mechanisms has the main goal of maximizing lifetime of the network. An efficient energy model is one that reveals the energy consumption at different node stage and components in the network. Processor energy model, transmitter energy model, sensor and node energy model are to be evaluated for calculating the energy level of the network (Zhou et al. 2011).

## II. LITERATURE SURVEY

A detailed survey on wireless sensor networks, their architecture and common standards followed for various applications were discussed in detail by many authors. (Akyildiz et al. 2001, Perillo et al. 2004 and Heinzelman et al. 2002) gives a clear overview of sensor networks stating the potential applications, the factors influencing sensor network design, criteria to be followed during network deployment and network communication architecture.

**Table 2.1 Comparison of MAC Protocols**

Protocol	Type	Techniques and Access method	Energy saving mechanism
SMAC (John Heidemann 2002)	Contention based (Synchronous)	Adaptive Listening using Fixed Duty Cycle Uses either TDMA or CSMA	Low and suffers from Latency
T-MAC (T.V. Dam 2003)	Contention based (Synchronous)	Uses FTS (Future Request To Send) packets, Uses Adaptive Duty cycle, Concept of Overhearing	High but suffers from early sleeping problem
TRAMA V. (Rajendran 2003)	Contention based (Synchronous)	Adaptive Assignment using TDMA	High
B-MAC (Joseph 2004)	Contention based (Asynchronous)	Low Power Listening	Medium and suffers from the problem of overhearing
WISE-MAC (Amre El-Hoiydi 2004)	Contention based (Asynchronous)	Preamble Sampling, Synchronized	High. Latency at every hop
PRIMA (Ben-Othman 2011)	Hybrid	Queuing model as classifier, TDMA and CSMA	High energy saving under prioritized traffic
PW-MAC (Lei Tang 2011)	Asynchronous	Predictive wakeup	Very high even during multiple traffic flows

A number of clustering protocols are proposed to reduce the power consumption in the network. Such protocols and techniques are given by authors (Teixeira et al. 2004, Zeghilet et al. 2009). (Ye and Mohamadian 2014) explains clustering based dynamic routing protocol based on Ant Colony optimization technique to increase the life span combined with energy reduction in networks An Intra and Inter-cluster communication model for Underwater Wireless Sensor Networks (UWSN) have been proposed by (Nitin Goyal et al. 2016) which adopts a fuzzy approach for effective selection of Cluster Head (CH) and estimation of cluster size. For intra-cluster communication, Minimum Average Routing Path (MARPCP) clustering method is implemented. Energy Conservative Multitier Architecture with Data Reduction for Cluster-Based Wireless Sensor Networks (ECMTADR) (Taner Cevik 2015) aims at data reduction, load balance and topology control. It performs best when compared to LEACH and HEED. Data repetition is avoided by using a special parameter called SCPR. The topology construction is based on hexagonal clusters and a CH is chosen within each cluster.

### III. INTER-CLUSTER COMMUNICATION USING PRIORITY QUEUES AND RELIABILITY MODELS

The most important design goal of a reliable system includes avoiding latency for immediate data reporting for active monitoring systems in contrast to passive monitoring systems. Many strategies need to be followed to avoid delay and jitter. Data delivery does not only depend on reliability but also on other parameters like congestion, energy consumption, throughput and delay. Factors affecting reliability of data includes the appropriate choice of the

route from source to the destination depending on the energy status of the intermediate nodes, level of data reliability, capacity of the link, congestion status mechanism usually implemented using queuing model, data collected from appropriate sensing area, choice of data transmission either using hop-by-hop or end-to-end approach, selection of suitable acknowledgement method, packet header length, choice of topology and implementation of cross layer protocol design (Kosanovic et al. 2008).

#### A. Reliability Models

Wireless Sensor Networks mostly use multi-hop communication. Sometimes the communication between the member nodes and the leader nodes may involve only single hop communication. Single hop model otherwise commonly stated as Hop-by-Hop model is most suitable only for static environments. In this communication model, only two nodes are involved in data communication namely the sender and the receiver. Upon sending a data packet from the source, the acknowledgment (ACK) is sent back by the receiver. Once the source receives the ACK, it discards the data packet that is stored in the buffer of the current node.

#### B. Energy Efficient and Reliable Hybrid Transport Protocol (EERHTP)

Energy Efficient and Reliable Hybrid Transport Protocol (EERHTP) follows N-hop ACK model and NACK model. As the scalability of networks increases, there is a need for N-hop reliability model as given in Fig. 5.1 where a copy of the data is retained in the buffer of the source node till the data properly reaches the destination through the use of Explicit Acknowledgements (EACK). The data storage in the buffer may lead to overhead but packet loss could be avoided. When the packet reaches the destination, it sends back an EACK back to the node that forwarded the data to the BS. This node is probably the Leader Node (LN). This LN again forwards an EACK back to the LN node that forwarded the data packet. In this way, EACK will travel backward to all the nodes that are on the way from destination to source node. Once EACK arrives at a particular node, the copy of the data packet will be removed from the nodes buffer. The advantage of using this hop-by-hop reliability model when compared to end-to-end model is that retransmission is easy when a packet loss occurs and data can be easily retrieved using hop-by-hop model.

#### C. Congestion and Queue Model in EERHTP

Congestion control is a very important point to be considered in application specific areas of sensor networks. Sometimes the flow of data becomes greater than the capacity of the available channels. When data traffic increases, congestion occurs leading to data loss. Therefore congestion detection and avoidance have become necessary in most of the real time applications. Many of the routing protocols that are developed in the recent years have incorporated automatic congestion detection and avoidance mechanisms. Some protocols perform congestion at the sink leading to a heavy loss of data while some try to alleviate congestion at the node itself. In time critical applications, reliability of the system is mostly ensured by avoiding congestion by enforcing priority mechanism.

**IV. ALGORITHM FOR EERHTP USING RELIABILITY SCHEMES**

**Variables:**

- DPin Data Packet
- PQ Priority Queue
- BS Base Station
- ACK Acknowledgement
- NACK Negative Acknowledgement

**Algorithm:**

- Step 1:** If DPin in PQ then do steps (2) to (7)  
Else  
If DPin in NPQ then do steps (8) to (9)
- Step 2:** Initialize the value of step counter = 0.
- Step 3:** Send DPin to the next hop node to the BS through a proper routing algorithm and Increment the step counter value by 1.
- Step 4:** Save the copy of DPin in the buffer of the intermediate node.
- Step 5:** Repeat Step (3) and (4) until DPin reaches the BS.
- Step 6:** When DPin reaches BS, ACK is sent by BS downward to the intermediate nodes till the source node receives ACK.
- Step 7:** In case of ACK loss, the data is retransmitted from the previous intermediate node, otherwise return.
- Step 8:** Send DPin to the next hop node to the BS through a proper routing algorithm to BS.
- Step 9:** If BS doesn't receive DPin within timeout period, then send NACK to the source node.
- Step 10:** Return.

**V. PERFORMANCE ANALYSIS AND RESULTS**

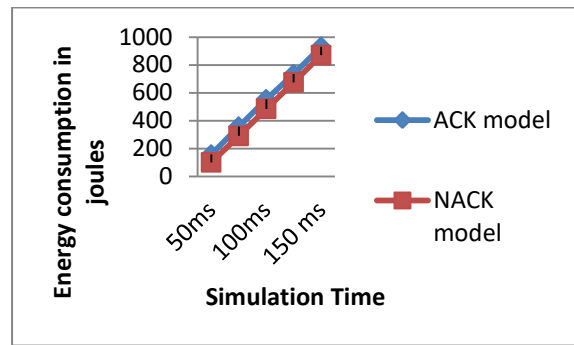
The energy and reliability metrics are evaluated for EERHTP based on ACK and NACK model. The results are tabulated and comparative graph shows the performance of various metrics.

**Table 5.1 Simulation Parameters for EEERHTP**

Parameters	Value
Number of nodes	100
Simulation time	150ms
Area Size	500 X 500 m
Buffer Size	15 packets
Sending gap	25ms
No of packets created	100 packets

**Table 5.2 Total Energy Consumption in EERHTP**

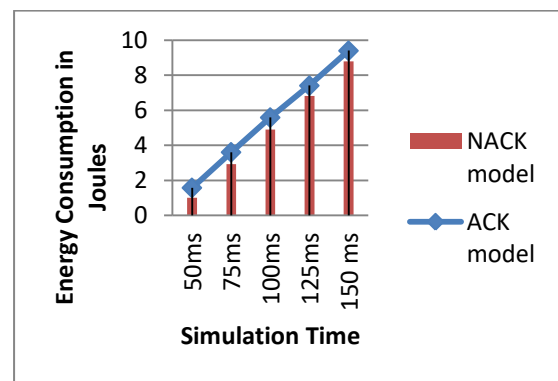
Simulation Time (ms)	Total Energy Consumption (Joules)	
	ACK Model	NACK model
50	156.498	100.67
75	357.306	290.153
100	553.46	485.017
125	733.612	675.022
150	930.519	870.191



**Figure 5.1: Energy Consumption in EERHTP Protocol**

**Table 5.3 Average Energy Consumption per Node in EERHTP**

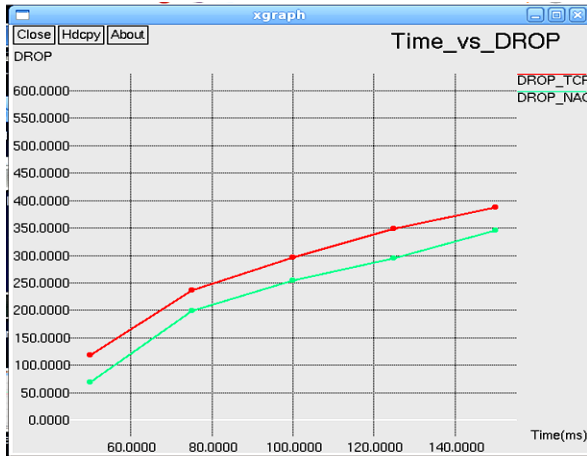
Simulation Time (ms)	Average Energy Consumption Per Node (Joules)	
	ACK Model	NACK model
50	1.58079	1.01686
75	3.60915	2.93084
100	5.5905	4.89916
125	7.41022	6.8184
150	9.39919	8.78981



**Figure 5.2: Average Energy Consumption for EERHTP**

**Table 5.4 Comparison of Packet Drop for EERHTP**

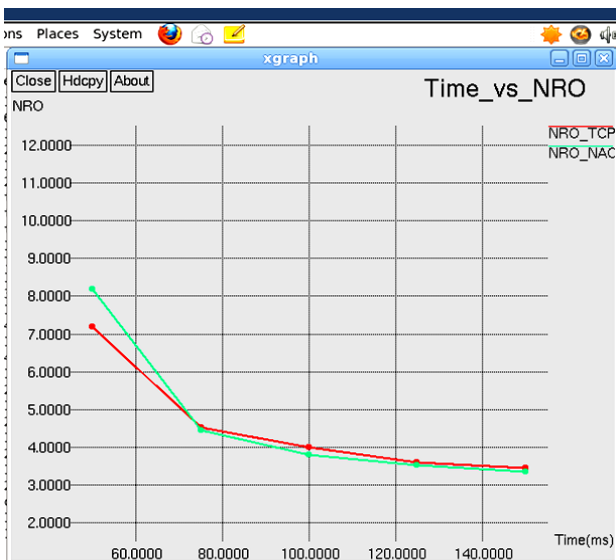
Simulation Time (ms)	Packet Drop	
	ACK Model (ms)	NACK model (ms)
50	118	69
75	237	199
100	297	255
125	349	295
150	388	346



**Figure 5.3: Packet Drop Vs Simulation Time**

**Table 5.5 Comparison of Network Routing Overhead for EERHTP**

Simulation Time (ms)	Network Routing Overhead	
	ACK Model	NACK model
50	7.19677	8.18171
75	4.52446	4.44182
100	3.99175	3.80444
125	3.59036	3.51283
150	3.4432	3.34255



**Figure 5.4: Routing Overhead for Reliability Models**

**Table 5.6 Comparison of Throughput for EERHTP**

Simulation Time (ms)	Throughput	
	ACK Model	NACK model
50	331.846	278.049
75	428.048	423.141
100	446.262	454.364
125	483.311	479.081
150	485.945	490.573

**VI. CONCLUSION**

Energy Efficient and Reliable Hybrid Transport Protocol (EERHTP) is very efficient achieving its goal of ensuring reliability by detecting and avoiding congestion using the concept of queue thresholds and priority levels. It also uses N-hop reliability model and various types of acknowledgements schemes for different types of data transmission. All these factors contribute to reduction in congestion and ensure that the data is delivered at the right time to the destined node. The proposed work EERHTP could be compared with Hierarchical Energy Efficient Reliable Transport Protocol (HEERTP) by Mohanty (2016) that achieves end-to-end reliability using a hop-by-hop acknowledgement scheme. The simulation results reveal that HEERTP achieves better performance in terms of energy efficiency, latency and reliability.

**REFERENCES**

1. Jalel Ben-Othman Lynda Mokdad , Bashir Yahya , An Energy Efficient Priority-based QoS MAC Protocol for Wireless Sensor Networks , IEEE ICC 2011.
2. Vergados, D. J., Pantazis, N.A. and Vergados D.D. (2014) ‘Energy-Efficient Route Selection Strategies for Wireless Sensor Networks’, DOI: 10.1007/s11036-008-0098-5.
3. Zhou, H-Y., Luo, D.Y., Gao, Y., Zuo, D.C. (2011) ‘Modeling of Node Energy Consumption for Wireless Sensor Networks’, Wireless Sensor Network, doi:10.4236/wsn.2011.31003, Vol. 3, pp. 18-23.
4. Yao, X-W., Wang, W-L., Wua, T-C., Yao, X-M. and Yang, S-H .(2013)‘A Novel Hybrid Slot Allocation Mechanism for 802.11e EDCA Protocol’, Elsevier B.V.
5. Ye, W., Heidemann J. and Estrin, D. (2004)‘Medium Access Control with Coordinated Adaptive Sleeping for Wireless Sensor Networks’, IEEE/ACM Transactions on Networking, Vol. 12.
6. Ye, Z. and Mohamadian, H. (2014) ‘Adaptive Clustering Based Dynamic Routing of Wireless Sensor Networks via Generalized Ant Colony Optimization’, International Conference on Future Information Engineering, Elsevier .
7. Tang, L., Sun, Y., Gurewitz, O., Johnson, D.B. (2011) ‘PW-MAC: An Energy-Efficient Predictive Wakeup MAC Protocol for Wireless Sensor Networks’, IEEE.
8. Teixeira, I., Rezende J. F. and Pedroza, A.C.P. (2004) ‘Wireless Sensor Network: Improving the Network Energy Consumption’, Journal of Telecommunications.
9. Thenmozhi E. and Audithan, S. (2015)‘Energy Efficient Cluster Head Selection and Data Convening in Wireless Sensor Networks’, Indian Journal of Science and Technology, Vol. 9(15).



14. 10.Shweta, Varsha, Kuldeep, (2014)‘Energy Efficient MAC Protocols For Wireless Sensor Network’, International Journal on Computational Sciences & Applications (IJCSA), Vol.4, No.1.
15. 11.Singh, S.P. and Sharma, S.C. (2015)‘A survey of Cluster based routing Protocols in Wireless Sensor Networks’, Elsevier, ICACTA.
16. 12.Singh, S.P. and Sharma, S.C. (2016) ‘Secure Clustering Protocols in Wireless Sensor Networks’, Journal of Wireless Sensor Networks.
17. 13.Sivakumar P., Amirthavalli K. and Senthil M. (2014) ‘Power Conservation and Security Enhancement in Wireless Sensor Networks: A Priority based Approach’, International Journal of Distributed Sensor Networks,Hindawi Publishing Corporation.

### AUTHORS PROFILE



**Dr.S.Prakasam** received his B.Sc (Mathematics) and M.C.A form Madras University and he received his Ph.D from SCSVMV University. He has 19 years of teaching experience. He is currently serving as Associate Professor, Computer Science and Applications Department, Sri Chandrasekharendra Saraswathi Viswa Mahavidyalaya (SCSVMV) University, Enathur, Kanchipuram. His research interests include Knowledge Engineering, Data Communications. He has presented ten papers in international conference and he is the author of 55 papers in international journals of repute. He has guided 40 M.Phil., and 9 Ph.D(3 completed and currently 6 scholars doing the research under his guidance ).