International Journal of Computer Networks & Communications (IJCNC) Vol.2, No.5, September 2010

A Reliable and Energy Efficient Transport Protocol for Wireless Sensor Networks

Kamal Kumar Sharma[1], Ram Bahadur Patel[2], Harbhajan Singh[3]

[1]Department of Electronics and Communication Engineering, RDJ Faculty of Engineering Dist
Mohali Punjab, INDIA
kamalsharma111@gmail.com
[2]Department of Computer Engineering, MIT Deemed University, Laxamngarh Rajasthan INDIA
patel_r_b@yahoo.co.in
[3]Department of Electronics and Comm Engineering, SSIET, Derabassi, Punjab INDIA
headsttp@yahoo.com

ABSTRACT

In wireless sensor networks (WSN), an ideal transport layer needs to support reliable message delivery and provide congestion control in an efficient manner in order to extend the lifetime of a WSN. The main use of transport protocol in WSN is to overcome the congestion and the reliability with energy efficiency. In this paper, we develop a reliable and energy efficient transport protocol (REETP), which mainly focuses on the reliability and energy efficiency. Our proposed protocol consist of an Efficient Node Selection Algorithm to determine a set of efficient nodes called E-Nodes which form a near optimal coverage set with largest area and highest residual energy level. The key idea of REETP is to transfer encoded packets using LT codes from the source to the sink block by block and each block is forwarded to an E-node. After receiving encoded packets, the E-node tries to reconstruct the original data packets and it encodes the original data packets again and relays them to the next E-node until it reaches the sink. By simulation results, we show that our proposed protocol has more packet delivery ratio with reduced packet loss and energy consumption.

KEYWORDS

Wireless sensor networks, Congestion, Contention, Energy Efficient, Transmission rate, Data flow

1. INTRODUCTION

1.1 Wireless Sensor Networks

Wireless Sensor Networks (WSNs) are highly distributed self-organized systems and depends upon a particular number of scattered low cost small devices. These devices include some strong demerits in terms of processing, memory, communications and energy capabilities. Sensor nodes collect measurements of interest over a given space and make them available to external systems and networks at sink nodes. The power saving techniques is commonly implemented to increase the independence of the individual nodes and this technique makes the nodes to sleep most of the time. This can be balanced with low power communications which usually lead to multi hop data transmission from sensor nodes to sink nodes and vice versa [1]. In order to collect the data, WSN uses an event-driven model and depends upon the collective effort of the sensor nodes in the network. Greater accuracy, larger coverage area and extraction of localized features are some of the advantages of the event-driven model over the traditional sensing. It is important that the preferred events are reliably transported to the sink for realizing these potential gains [2]. Habitat monitoring, in-door monitoring, target tracking and security surveillance are some of the

DOI : 10.5121/ijcnc.2010.2506

applications where WSNs can be used. WSNs have some problems to be overcome such as energy conservation, congestion control, reliability data dissemination, security and management of a WSN itself. These problems often take part in one or more layers from application layer to physical layer and it can be studied separately in each corresponding layer or collaboratively cross each layer. For example, congestion control may involve only in transport layer but the energy conservation may be related to physical layer, data link layer, network layer and higher layers [3].

1.2 Transport Protocols in WSN

The transport protocols in WSN should support

- Reliable message delivery,
- Congestion control, and
- Energy efficiency.

The requirement for transport layer protocol in WSN has been discussed. The following are the suggestions given by the researchers [4]:

- Loss detection and recovery can be handled below the transport layer and mitigated using data aggregation
- Congestion is not an issue because sensor nodes spend most of the time sleeping resulting in sparse traffic in the network

Generally the deployment of sensor nodes produces congestion in WSN in the contradiction to the above arguments against the need for a transport layer protocol. In the absence of congestion control, data from sensor nodes to sink may suffer from channel contention which in turn decreases the ability of the sensor nodes to deliver data to the sink. Since the layers under the transport layer do not provide guaranteed end-to-end reliability, it is inadequate to depend upon the loss detection and reliability techniques, in the situation where data's are delivered reliably in WSNs [4].

Like other networks, WSNs should have a transport layer in order to posses reliable message delivery and congestion control. An ideal transport layer needs to support reliable message delivery and provide congestion control in an efficient manner in order to extend the lifetime of a WSN [4].

The following are the some of the transport protocols developed in the wireless sensor networks [5]:

- TCP/IP – Transmission Control Protocol
- PCCP - Priority-based Congestion Control Protocol
- STCP - Sensor Transmission Control Protocol [6]
- MQQT – Message Queuing Telemetry Transport [7]
- PORT - Price-Oriented Reliable Transport Protocol [8]
- PSFQ - Pump Slowly, Fetch Quickly [9]
- RMST - Reliable Multi-Segment Transport [10]
- ESRT - Event to Sink Reliable Transport [11]

Except STCP, the above mentioned protocols consider either congestion control or reliability guarantees. Some protocols use end-to-end and others hop-by-hop controls and also some guarantees event reliability and others provide packet reliability. The following are the two fundamental demerits of the existing protocols for WSNs [5]:

- Since sensor nodes in WSNs can be installed with different kinds of sensors and used in different geographical locations, it may have different priorities.
- The existing transport protocols for WSNs assume that single path routing us used in the network layer without considering the multipath routing.

We summarize the requirements of a transport layer protocol for sensor networks as follows [6]:

- **Generic:** The transport layer protocol should be independent of the application, Network and MAC layer protocols to be applicable for several deployment scenarios.
- **Heterogeneous data flow support:** Continuous and event-driven flows should be supported in the same network.
- **Controlled variable reliability:** Some applications require complete reliability while others might tolerate the loss of a few packets. The transport layer protocol should leverage this fact and conserve energy at the nodes.
- **Congestion detection and avoidance:** The congestion detection and avoidance mechanism helps in reducing packet retransmissions, thereby conserving energy.
- **Base station controlled network:** Since sensor nodes are energy constrained and limited in computational capabilities, majority of the functionalities and computation intensive tasks should be performed by the base station.
- **Scalability:** Sensor networks may comprise of large number of nodes, hence the protocol should be scalable.
- **Future enhancements and optimizations:** The protocol should be adaptable for future optimizations to improve network performance and support new applications.

The main use of transport protocol in the wireless sensor networks is to overcome the congestion and the reliability with energy efficiency. In this paper we develop a reliable and energy efficient transport protocol, which mainly focus on the reliability and energy efficiency. The paper is organized as follows. Section 2 presents the related work done and section 3 presents the Efficient Node Selection Algorithm. The LT coding technique is described in section 4 and the proposed reliable and energy efficient transport protocol is presented in section 5. Section 6 presents the simulation results and the paper is concluded in section 7.

2. Related Work

Sandip Dalvi et al [2] have proposed a transport protocol which provides the desired event reliability to the application, by distributing the load at a sensor among its children based on their residual energies and average MAC layer data rate. The event rate distribution happens in such a way that the application at the sink gets its required event rate and the overall energy consumption of nodes is minimized. They have derived a method for computing average MAC data rate for these two protocols and using simulations they have shown that our transport protocol performs close to optimal.

Nurcan Tezcan et al [12] have addressed the problem of reliable data transferring by first defining event reliability and query reliability to match the unique characteristics of WSNs. They have considered event delivery in conjunction with query delivery. They have proposed an energy-aware sensor classification algorithm to construct a network topology that is composed of sensors in providing desired level of event and query reliability. They have analyzed their approach by taking asymmetric traffic characteristics into account and incorporating a distributed congestion control mechanism. They have evaluated the performance of their proposed approach through an ns-2 based simulation and show that significant savings on communication costs are attainable while achieving event and query reliability.

Yao-Nan Lien et al [13] has proposed the Hop-by-Hop TCP protocol for sensor networks aiming to accelerate reliable packet delivery. Hop-by-Hop TCP makes every intermediate node in the transmission path execute a light-weight local TCP to guarantee the transmission of each packet on each link. It takes less time in average to deliver a packet in an error-prone environment.

Sunil Kumar et al [14] have studied the performance of ESRT in the presence of over-demanding event reliability, using both the analytical and simulation approaches. They have shown that the ESRT protocol does not achieve optimum reliability and begins to fluctuate between two inefficient network states. With insights from update mechanism in ESRT, they have proposed a new algorithm, called enhanced ESRT (E2SRT), to solve the over-demanding event reliability problem and to stabilize the network. Their simulation results show that their E2SRT outperforms ESRT in terms of both reliability and energy consumption in the presence of over-demanding event reliability. It also ensures robust convergence in the presence of dynamic network environments.

Damayanti Datta et al [15] have proposed a new protocol for reliable data transfer in time-critical applications with zero tolerance for data loss in wireless sensor networks which uses less time and fewer messages in comparison to an established protocol PSFQ. The two key features of their proposed protocol are out-of-sequence forwarding of packets with a priority order for sending different types of messages at nodes and delaying the requests for missing packets. They have also presented two methods for computation of the delay in requesting missing packets.

3. Efficient Node Selection Algorithm

Before discussing our proposed reliable and energy efficient transport protocol (REETP) in detail, we present an Efficient Node Selection Algorithm (Algorithm 1). In the efficient node selection algorithm, we determine a set of efficient nodes called E-Nodes which form a near optimal coverage with set with largest area and highest residual energy level.

Also we assume that sensors are able to monitor their residual energy because many electronic devices are equipped with energy monitoring functions. The energy level (EL) of sensors s_i at the beginning of update interval (UI), denoted by EL is calculated as:

$$EL = \frac{RE(UI)}{IE} \tag{1}$$

Where IE is the initial energy corresponding to fully charged battery and RE (UI) is the residual energy of sensors s_i at the beginning of the update interval.

In each iteration, Algorithm 1 selects one node from the unselected sensors which covers the largest area with highest residual energy level. For this purpose, a weight value is defined to represent the weight of a sensing region of a sensor based on its residual energy. For a given region, the weight value based on the residual energy level of a sensor is:

$$W(R_i) = EL \times A(R_i) \tag{2}$$

Where EL is the energy level given in (1) and A (R_i) is the area of sensing region R_i.

Then, we calculate the gain of selecting each sensor using the weight value. To do this, we first find the size of the area that can be covered by sensor s_i and has not been covered yet. Consider the sensor s_i with sensing region Ri. Let R_{CS} be the area that sensors of C covered so far, i.e., $R_{CS} = \bigcup_{s_j \in C} R_j$. Beneficial area of s_i is defined to be the region inside the sensing field which has not been covered, i.e., $RB = (R_i \cap A)/R_{CS}$. Hence, gain function for sensor s_i is the total weight of its beneficial area, which is given as:

$$G(Si) = W(RB),\ s_j \in C \tag{3}$$

Where G(Si) is the gain function and RB is the beneficial area.

Algorithm 1 is to find a near-optimal coverage set C. Then each member of the set C is known as an E-node.

Algorithm 1

```
1. Let $C = \Phi$
2. Let $R_{CS}$ be the total sensing region of C
3. Let $S-C = \{s_1, s_2 \ldots s_n\}$
4. $G_{max} = 0$
5. For each $s_i \in S - C$
6.     Calculate the energy gain of $s_i$
           $G(s_i) := \sum_{aj \in (R \cap A)/RCS} W_i(aj)$
7      If ($EL_B \geq G_{max}$)
               $G_{max} = G$
               temp: = $s_i$
       End if
8. End for
```

```
9. $C = C \cup temp$
10. If $A \subseteq R_{CS}$, then
        Return C
    Else
        Repeat from 3
    End if
```

4. FEC using LT Codes

LT codes are rateless because the number of encoding symbols which are generated from the data is unlimited. The required encoding symbols can be generated immediately. From any set of the generated encoding symbols, an exact copy of the data can be recovered by the decoder. Thus the required encoding symbols can be generated without depending on the loss model on the erasure channel. In order to recover the data, the generated symbols are sent over the erasure channel until the adequate number has been arrived at the decoder. The LT codes are near optimal with respect to any erasure channel because the decoder can recover the data from the near optimal number of possible encoding symbols. Moreover, as a function of the data length, the encoding and decoding times are very efficient. When compared with the previous erasure codes, LT codes provide various advantages for different types of data delivery applications. Using LT codes, the minimal number of encoding symbols can be generated and send the packets to the receivers. The minimal number of encoded symbols is required to recover the original data from each receiver [16].

Robust distributed storage, delivery of streaming content, delivery of content to mobile clients in wireless networks, peer-to-peer applications and delivery of content along multiple paths in order to ensure resiliency to network disruptions, are some of the other applications of the LT codes [16].

4.1. LT Process

The preferable length L of the encoding symbols can be selected. Due to the overheads with the accounting operations, the overall encoding and decoding is more efficient for larger values of L and this value does not have any influence on the history. Sometimes the length L is selected to be closer to the length of the packet payload in case of transport applications [16].

4.1.1 Encoding: The data of length N is partitioned into K=N / L input symbols such that each transport symbol is of length of L. Each encoding symbols are connected with a key. In order to produce the degree and set of neighbors of the encoding symbol, both the encoder and decoder applies the same function to the key. In order to generate an encoding symbol, the encoding symbol may choose each key randomly and this key is passed to the decoder along with the encoding symbols. Alternatively, each key may be produced by a deterministic process, e.g., each key may be larger than the previous key. The encoder and decoder have the access to the same set of random bits. In order to produce the degree and the neighbors of the encoding symbol, each key is used as the seed to a pseudo-random generator which uses these random bits [16].

4.1.2 Decoding: For a given group of encoding symbols and some illustrations of their associated degrees and sets of neighbors, the decoder recovers the input symbols repeatedly using the following rule as long as it applies [16].

Since the neighbor is a copy of the encoding symbol, it can be recovered immediately if there is at least one encoding symbol which has exactly one neighbor. The value of the recovered input symbol is XORed into any remaining encoding symbols that also have that input symbol as a neighbor. The recovered input symbol is removed as a neighbor from each of these encoding symbols and the degree of each such encoding symbol is decreased by one to reflect this removal [16].

5. Proposed Reliable and Energy Efficient Transport Protocol (REETP)

The key idea of the Reliable and Energy Efficient Transport Protocol (REETP) is to transfer encoded packets using LT codes, block by block. In order to reconstruct the original data packets, the receiver has to receive sufficient encoded packets. The REETP has to guarantee that the receiver can receive enough encoded packets in such a limited time interval. By setting the block size n (i.e., the number of original data packets in each block) appropriately, REETP can control the transmission time and allow the receiver to be able to receive enough packets in order to reconstruct original block even in node motion.

In REETP, a data source first groups data packets into blocks of size n. Then the source encodes these blocks of packets, and sends the encoded blocks into the network. The data packets are forwarded from the source to the sink block by block, and each block is forwarded to an E-node. In each E-node relay, the sender first estimates the number of packets needed to send for the E-node to reconstruct the original packets. We call this number as "MaxPacket". Within the MaxPacket, the sender pushes the encoded packets to the network fast. When the packet is reached, the sender slows down pack transmission, waiting for a positive feedback from the E-node. After receiving encoded packets, the receiver tries to reconstruct the original data packets. If the reconstruction is successful, it sends back a positive feedback. Upon the reception of a feedback, the sender stops sending packets, while the E-node encodes the original data packets again and relays them to the next E-node until the sink is reached. The operations performed on the sender and the receiver (E-node) is described in the following.

REETP Sender:

1) Estimates the MaxPacket.
2) Encodes a block using LT codes.
3) Pumps encoded packets fast in a random order within the MaxPacket.
4) Sends encoded packets slowly outside the MaxPacket. until receiving a positive feedback from the E-node.

REETP Receiver:

1) Keeps receiving packets until it can reconstruct the original data packets, and sends a positive feedback to the Sender.
2) Encodes the reconstructed packets again and relay them to the next E-node.

From the above description, we can see that REETP reduces the burden of the sender and the receiver by requiring only one feedback per block. The sender has no additional responsibilities except encoding and injecting packets, and the receiver only needs to send one feedback after reconstructing the original packets.

6. Experimental Results

6.1 Simulation Model and Parameters

We use NS2 [17] to simulate our proposed protocol. In our simulation, the channel capacity of mobile hosts is set to the same value: 2 Mbps. We use the distributed coordination function (DCF) of IEEE 802.11 as the MAC layer protocol.

In our simulation, 100 sensor nodes are deployed in a 1000 mr x 1000 m region for 50 seconds simulation time. All nodes have the same transmission range of 250 meters. The simulated traffic is Constant Bit Rate (CBR). The simulation settings are summarized in the following table. (Table 1) .

No. of Nodes	100
Area Size	1000 X 1000
Mac	802.11
Simulation Time	50 sec
Traffic Source	CBR
Packet Size	512
Transmit Power	0.360 w
Receiving Power	0.395 w
Idle Power	0.335 w
Initial Energy	3.1 J
No. of sources	2,4,6,8
Transmission Rate	250,500,750 and 1000 kb.

Table: 1

6.2 Performance Metrics

We compare the performance of our proposed REETP protocol with A MAC-aware Energy Efficient Reliable Transport Protocol (MAEERTP) [2] for WSN. We evaluate mainly the performance according to the following metrics:

Average Energy Consumption: The average energy consumed by the nodes in receiving and sending the packets are measured.

Packet Delivery Ratio: It is the ratio of the fraction of packets received successfully and the total no. of packets sent.

Average Packet Loss: It is average number of packets lost at each receiver and the sink. The performance results are presented graphically in the next section.

6.3 Results

A. Varying No. of Sources

In the first experiment, in order to study the impact of increased the number of sources, we vary the no. of sources as 2, 4, 6 and 8 and measure the performance of the protocols.

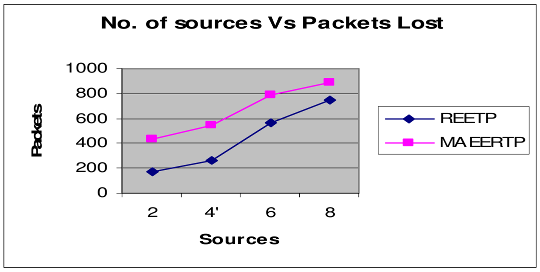

Fig: 1 No. of Sources Vs Packets Lost

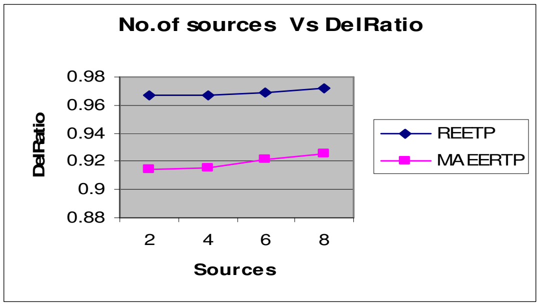

Fig: 2 No. of Sources Vs DelRatio

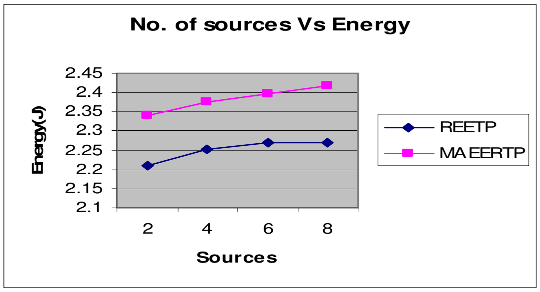

Fig: 3 No. of Sources Vs Energy

Fig.1 shows the packet lost obtained with our REETP protocol compared with MAEERTP protocol. It shows that the packet lost is significantly less than the MAEERTP, as sources increases.

From Fig. 2, we can see that the packet delivery Ratio (PDR) for REETP increases, when compared to MAEERTP protocol.

Fig. 3 shows that the average energy consumed by the nodes in receiving and sending the data. Since REETP make use of energy efficient scheduling, the values are considerably less in REETP when compared with MAEERTP protocol.

B. Varying the Transmission Rate

In the second experiment, in order to study the performance of increased traffic sending rate, we vary the transmission rate as 100,200,300,400 and 500Kb to measure the performance of the protocols.

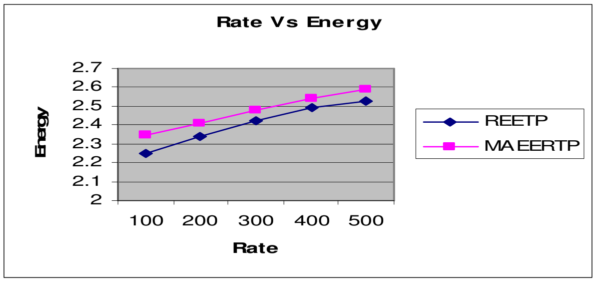

Fig: 4 Rate Vs Energy

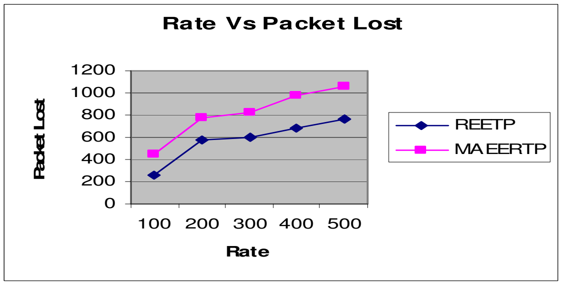

Fig: 5 Rate Vs Packet Lost

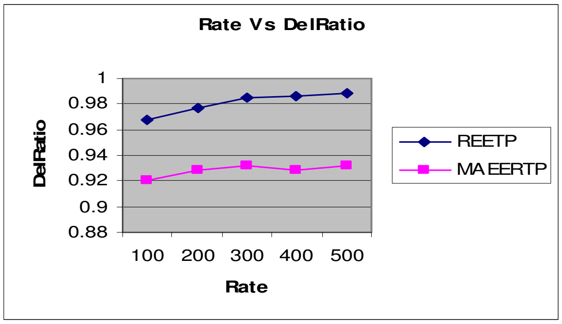

Fig: 6 Rate Vs Del Ratio

Fig. 4 shows that the average energy consumed by the nodes in receiving and sending the data. Since REETP make use of energy efficient scheduling, the values are considerably less in REETP when compared with MAEERTP protocol.

Fig.5 shows the packet lost obtained with our REETP protocol compared with MAEERTP protocol. It shows that the packet lost is significantly less than the MAEERTP, as rate increases.

From Fig. 6, we can see that the packet delivery Ratio (PDR) for REETP increases, when compared to MAEERTP protocol.

7. CONCLUSIONS

In this paper, we have developed a reliable and energy efficient transport protocol (REETP), which mainly focuses on the reliability and energy efficiency. Our proposed protocol consist of an Efficient Node Selection Algorithm to determine a set of efficient nodes called E-Nodes which form a near optimal coverage set with largest area and highest residual energy level. The objective of REETP is to transfer encoded packets using LT erasure codes from the source to the sink block by block and each block is forwarded to an E-node. The sender first estimates MaxPacket which is the number of packets needed to send for the E-node to reconstruct the original packets. When the packet is reached, the sender slows down pack transmission, waiting for a positive feedback from the E-node. After receiving encoded packets, the receiver tries to reconstruct the original data packets. If the reconstruction is successful, it sends back a positive feedback. Upon the reception of a feedback, the sender stops sending packets, while the E-node encodes the original data packets again and relays them to the next E-node. By our simulation results, we have shown that our proposed protocol has more packet delivery ratio with reduced packet loss and energy consumption.

REFERENCES

1. Paulo Rogerio Pereira, Antonio Grilo, Francisco Rocha, Mario Serafim Nunes, Augusto Casaca, Claude Chaudet, Peter Almström and Mikael Johansson, “End-To-End Reliability in Wireless Sensor Networks: Survey and Research Challenges”, Euro FGI Workshop on IP QoS and Traffic Control, 2007.
2. Sandip Dalvi, Anirudha Sahoo and Ashutosh Deo, “A MAC-aware Energy Efficient Reliable Transport Protocol for Wireless Sensor Networks”, In the Proceedings of the IEEE conference on Wireless Communications & Networking Conference, 2009.
3. Chonggang Wang, Kazem Sohraby, Bo Li and Weiwen Tang, “Issues of Transport Control Protocols for Wireless Sensor Networks”, In the Proceedings of International Conference on Communications, Circuits and Systems (ICCCAS), 2005.
4. Justin Jones and Mohammed Atiquzzaman, “Transport Protocols for Wireless Sensor Networks: State-of-the-Art and Future Directions”, International Journal of Distributed Sensor Networks, 2007.
5. Chonggang Wang, Kazem Sohraby, Bo Li, Mahmoud Daneshmand and Yueming Hu, “A Survey of Transport Protocols for Wireless Sensor Networks”, IEEE Networks, 2006
6. Yogesh G. Iyer, Shashidhar Gandham and S. Venkatesan, “STCP: A Generic Transport Layer Protocol for Wireless Sensor Networks”, In the Proc. of IEEE Intl. Conf. on Computer Communications and Networks (ICCCN), 2005.
7. Urs Hunkeler, Hong Linh Truong and Andy Stanford-Clark, “MQTT-S – A Publish/Subscribe Protocol For Wireless Sensor Networks”, In the Proc. of 2nd Workshop on Information Assurance for Middleware Communications, (IAMCOM), 2008.
8. Yangfan Zhou, Michael R. Lyu, Jiangchuan Liu and Hui Wang, “PORT: A Price-Oriented Reliable Transport Protocol for Wireless Sensor Networks”, Proceedings of the 16th IEEE International Symposium on Software Reliability Engineering, 2005.
9. Chieh-Yih Wan, Andrew T. Campbell and Lakshman Krishnamurthy, “PSFQ: A Reliable Transport Protocol for Wireless Sensor Networks”, In the Proceedings of the 1st ACM international workshop on Wireless sensor networks and applications, 2002.
10. Fred Stann and John Heidemann, “RMST: Reliable Data Transport in Sensor Networks”, In the 1st IEEE International Workshop on Sensor Net Protocols and Applications (SNPA), 2003.

11. Yogesh Sankarasubramaniam, Ozgur B. Akan and Ian F. Akyildiz, "ESRT: EventtoSink Reliable Transport in Wireless Sensor Networks", Proceedings of 4th ACM International symposium on Mobile ad hoc networking & computing, 2003.
12. Nurcan Tezcan and Wenye Wang, "ART: An Asymmetric and Reliable Transport Mechanism for Wireless Sensor Networks", International Journal of Sensor Networks, 2007.
13. Yao-Nan Lien, "Hop-by-Hop TCP for Sensor Networks", International Journal of Computer Networks & Communications (IJCNC), 2009
14. Sunil Kumar, Zhenhua Feng, Fei Hu and Yang Xiao, "E2SRT: enhanced event-to-sink reliable transport for wireless sensor networks", Wireless Communications and Mobile Computing, 2008.
15. Damayanti Datta and Sukhamay Kundu, "An Application-Specific Reliable Data Transfer Protocol in Wireless Sensor Networks", Journal of Networks, 2008
16. Michael Luby, "LT Codes", Proceedings of the 43rd Symposium on Foundations of Computer Science, 2002.
17. Dunkels, A., Alonso, J. and Voigt, T., "Making TCP/IP Viable for Wireless Sensor Networks". First European Workshop on Wireless Sensor Networks (EWSN'04), work-in-progress session, Berlin, Germany 2004
18. N. Riga , I. Matta , A. Medina , C. Partridge , J. Redi, "An energy-conscious transport protocol for multi-hop wireless networks", Proceedings of the 2007 ACM CoNEXT conference, New Work, 2007
19. Network Simulator: www.isi.edu/nsnam/ns

Authors short Bibliography

Kamal Kumar Sharma received B.Tech Degree in 2001 from S.K. Inst of Engineering and Technology, Kurukshetra university Kurukshetra in Electronics & communication Engineering, M.Tech in 2007 from Punjab Technical University, Jalandhar in Electronics & communication Engineering Department. He is doing Ph.D. in the field of wireless sensor networks from Punjab Technical University Jalandhar, INDIA. He is Associate Professor in Ram Devi Jindal college of Engineering and Technology, Punjab. He has published 13 research papers in International/National Journals and Refereed International Conferences and two books in his core field.

Dr. Ram Bahadur Patel received PhD from IIT Roorkee in Computer Science & Engineering, PDF from Highest Institute of Education, Science & Technology (HIEST), Athens, Greece, MS (Software Systems) from BITS Pilani and B. E. in Computer Engineering from M. M. M. Engineering College, Gorakhpur, UP. Dr. Patel is in teaching and Research & Development since 1991. He has supervised several M. Tech, and M. Phil and PhD Thesis. He is currently supervising several M. Tech, and PhD students. He has published more than 100 research papers in International/National Journals and Refereed International Conferences. Dr. Patel received several research awards. He is working as a professor in the department of Computer Engineering in MIT Deemed University Rajsthan INDIA.

Dr. Harbhajan Singh is a engineering graduate of 1976 from Institutions of Engineers Calcutta INDIA in Electronics & communication Engineering, and completed his Post graduate in Electronics Engineering from panjab Univeristy Chandigarh in 1983. Dr. Singh Completed his Ph.D. in 1987 in the field of ISDN and LAN. He is a Professor in Shree Sukhmani Institute of Engineering and Technology, Punjab. He has published more than 50 research papers in International/National Journals and Refereed International Conferences.