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ANALYSIS OF BACK-TO-BACK RELIABLE AND CONGESTION CONTROL TRANSPORT LAYER SUPPORTING PROTOCOL FOR WSN

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Abstract: In addition to the optimization of the hardware, the Wireless Sensor Network (WSN) protocol for communication between sensor nodes of varying capabilities (heterogeneous) is a very important factor in determining how long the network will remain operational, and it plays a much more important role than the optimization of the hardware. Researchers and investigators are working to expand the transport layer protocol among several layers of the heterogeneous WSN protocol hierarchy to ensure and prevent congestion issues in WSN and provide assistance with data or application volume reliability, thereby ensuring the Quality of Service (QoS). We try to analyze a transport protocol with a lightweight design, back-to-back dependability, and congestion management transport layer protocol in this research work (CCTLP). By introducing the idea of distributed recollection within the network and fully recovering from packet loss due to congestion by constructively executing congestion identification as well as its rate adaptation method that follows a stochastic control structure, this protocol achieves high data reliability.
TCP NewReno (TCP-NR), TCP Reno (TCP-R), and TCP Westwood are all subjected to an extensive analysis in comparison to the suggested method (TCP-WW). The CCTLP has had network topology confirmed, and the findings demonstrate that it effectively and efficiently reduces congestion. Additionally, it shows 0.3012 Mbps higher throughput, 100 msec average back-to-back (B-2-B) packet latency in data for heterogeneous packet information, 99.89% data packet reliability, and overall energy-efficient actions, such as the lowest per packet communication value in comparison to TCP-NP, TCP-R, and TCP.
Keywords: Transport layer, Reliability, MAC layer, Congestion.

INTRODUCTION

In order to monitor actions occurring in a specific region, wireless sensor networks (WSNs) are built by combining a lot or a bunch of sensor nodes. A CPU, some sort of memory, a transceiver, one or more sensors, and a battery are the parts that make up a sensor node [1]. The access point (AP) that connects the sensor community through one or more observers receives the data that were collected from the site. The observer is a stop consumer that is curious in learning more about the site that was found. [2]. The examination of the differences and similarities of the protocols used for the transport layer in wireless sensor networks is the primary topic of this research. Delivery protocols are used to lessen the occurrence of congestion and reduce the number of lost packets, as well as to ensure fairness in bandwidth distribution and back-to-back dependability [3]. Both the Transmission Control Protocol (TCP) [4] and the user Datagram Protocol (UDP) [5] are well-known transport protocols that are

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extensively used across the internet; however, neither one of these protocols is an option that is suitable for wireless sensor networks.

RELATED WORK

In this section, we will discuss the current transport protocol methods for WSN. These protocols aim to reduce congestion while also ensuring their networks are reliable. The key distinctions between these protocols in terms of their capacity to handle congestion and provide reliability help are laid out in Table 1, which may be seen below. In [6], the STCP (Sensor Transmission Control Protocol) places its whole reliance on the buffer occupancy while trying to determine whether or not there is congestion. It provides an implicit notification of congestion, and the avoidance of congestion is accomplished by cost modification as well as the redirection of site users (traffic). Within the community, controlled variable packet reliability may be achieved using STCP for flows. STCP provides B-2 B (Back to Back) dependability as well as loss recovery techniques for continuous and event-driven dataflows by making use of NACK and ACK in the appropriate order. The multimodal gliding of statistics, however, which is a need that is essential for heterogeneous applications, is not yet provided by STCP. DST (Delay Sensitive Transport Protocol) [7] uses implicit (Imp) congestion notification messages to inform the user of the severity of the congestion by identifying the congestion by considering the mote put off estimation in the same way as the buffer occupancy. Because of the supply rate adjustment method, congestion is avoided. However, DST does not offer an explicit (Exp) loss recovery solution for dropped packets despite supporting E-2-E event reliability.

Table 1: Transport Layer Protocols Comparison

Protocols	**RCRT**	**FLUSH**	**STCP**	**PORT**	**ART**	**CTCP**	**RT^2**	**DST**
Congestion Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Congestion Detection	Time to recover loss	Route length and link quality	Buffer size	Mote price andlink -loss rates	ACK received to "Essential motes"	Transmission error packet loss and Buffer size	Mote delay/ Buffer size	Mote delay/ Buffer size
Congestion Notification	Implicit	Implicit	Implicit	Implicit	Implicit	Explicit	Implicit	Implicit
Congestion	Cost	Cost	Traffic redirec	Traffic redirect	Reduce traffic of	Cost	Cost	Cost

Avoidance	Adjustment	Adjustment	tion / Cost adjustment	ion / Cost adjustment	"Nonessential motes"	Adjustment	Adjustment	Adjustment
Reliability Support	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Reliability Direction	Up	Up	Up	Up	Both	Up	Up	Up
Reliability Measure	Packet	Packet	Packet	Event information	Event	Packet	Packet	Event
Loss Recovery	B-to-B	B-to-B	B-to-B	……… …	B-to-B	H-b-H	H-b-H	B-to-B
Loss Notification	NAK & cumulative ACK	NAK	NAK/ ACK	……… ….	ACK (events)/ NACK (queries)	ACK/ Double ACK	SACK	

This technique identifies congestion by taking into account the buffer size, direction duration, and quality of the network. The results of this analysis are then communicated to the user in order to urge rate modifications. Upstream dependability is maintained via the process of flushing, which makes it possible for the E-2-E loss restoration method to be carried out with the assistance of NACK signaling. On the other side, PORT (rate-oriented reliable transport Protocol) [9] diagnoses congestion only based on "Node rate" and "link loss price." The number of times a packet is tried to be transmitted before it is successfully delivered to the sink is what is meant to be referred to when using the term "Node rate." To let the sink know how bad the congestion is, PORT sends Imp congestion notice messages. In order to minimize the congestion, PORT also employs source adjustments and site visitor diversion tactics. It is the simplest way to increase reliability in the other direction (E-2-E). It does not help the Exp mechanism recover packets since it relies on congestion control and premier routing to reduce congestion and packet loss. Its reliance on these two methods is the reason of this (to ensure dependability). Transmission error losses and buffer overflow are used by the Collaborative Transport Control Protocol (CTCP) [10] to evaluate whether active congestion is present. Users are kept apprised of the extent of the congestion by the use of congestion notice packets by the

Exp, and congestion is avoided through the use of price adjustment coverage. The usage of CTCP, which provides changeable packet reliability for noteworthy applications in the community, makes it feasible to acquire Hop-by-Hop dependability (H-b-H). H-b-H dependability may be obtained by using CTCP. The substantial use of controlling signaling overhead that CTCP makes allows for the guaranteeing of reliability. Congestion is identified for RCRT (price-control reliable delivery Protocol) and Network by the successful delivery of packets, and it is reported with Imp. A network is considered to be congested when it is unable to receive ACK messages in a consistent manner from key dominating sensor motes within a certain amount of time. On the other hand, RCRT relies on time estimation to determine where congestion is occurring in order to minimize the amount of loss. Both ACK and NACK, by their respective manipulations of signaling, contribute to the E-2-E loss repair pathway. NACK and ACK are used for event and question reliability, respectively, in order to assure reliability in both directions. On the other hand, RCRT employs NACK to ensure packet reliability in the upstream route and cumulative ack in order to safely delete the memory. Through the use of Exp selective-acknowledgments (SACK), the move-layer feature, and intermediate mote comments records, it is possible to accomplish reliable Hb-H loss recovery between actors. This is done in order to collect direction failures, congestion alarms, or transmission price feedbacks. It does this by analyzing data such as mote latency and buffer length and then utilizing the Imp technique to notify users of the situation when congestion is found.

PROPOSED PROTOCOL OVERVIEW

The majority of the communication between WSN sources and sinks is Hop-by-HOP. The failure of nodes, congestion, and packet collisions caused by hidden nodes are all major causes of packet loss in WSNs. For every packet loss in a WSN, there is a cost in terms of energy that must be paid, which is determined by-

$$E_{cost} = \eta_h (E_{NAK} \times \eta_s) joules (1)$$

Where, E_{cost} = total energy required for dropped packet transmission (joules)

η_h = Number of hops (between source and sink nodes)

E_{NAK} = Energy absorbed by node to transmit the NACK packet (joules)

η_s= Energy absorbed by node to deliver the actual missing packet (joule)

As a consequence of this, in order to cut down on the expense of the energy used by the node (or the energy used by the network), it is required to minimize the quantity of packet drop to an extent that fulfils the criteria of the program's specific Quality of Service. As a consequence of this, it is the responsibility of the shipping protocol to manage congestion, and if congestion does occur, it is the responsibility of the shipping protocol to alert the source nodes and have them adjust the rate at which they send data in order to successfully reduce congestion. When packet recovery is prioritized, the heterogeneous WSN delivery protocol takes advantage of its extra characteristic, which is scattered network capacity. This occurs when there is a need to priorities packet recovery. When the option to recover lost packets is chosen, this function is turned on automatically. It is impossible to prevent data loss in a WSN since it is constructed up of nodes that have limited energy resources. This makes it inevitable that data will be lost due to the dropping of packets as a consequence of a crowded community scenario. Not only is this valid from the point of view of the effectiveness of potentially beneficial application results, but it is also valid from the point of view of the use of energy. In the next step, we will be able to offer our preferred shipping protocol scheme, which we have decided to name CCTLP. This will take place in the next phase: The use of this protocol scheme will allow for the identification and avoidance of congestion, as well as the restoration of data that was previously lost. The CCTLP's block diagram is shown in Figure 1, which offers a graphical representation of the data. The creation of the suggested architecture makes use of the functional modules listed below, namely the Congestion Manipulation Module and the Reliability Module.

3.1 Congestion Control

The packet delay is given by-

$$\tau_{delay} = \tau_{ppt} + \tau_{iQ} + \tau_{pt} \tag{2}$$

Where, τ_{delay}= Average back-to-back packet delay (latency) in msec

τ_{ppt} = Average one-hop propagation time in msec

τ_{iQ}= Average node queue delay in msec

τ_{pt} = Average packet processing time at given node in msec

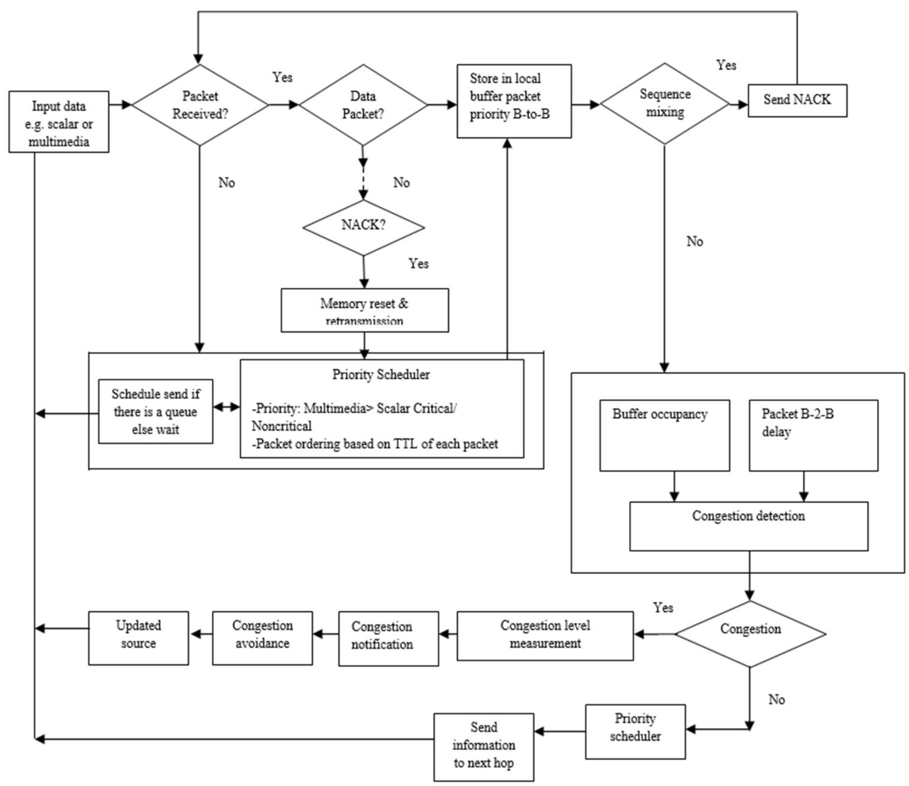

Fig. 1: Proposed transport protocol model

We defined C in (Congestion index) in milliseconds to emphasize the congestion condition of the network. This state is monitored by the buffer occupancy degree of the intermediate node and the B-to-B propagation delay. Detecting congestion required us to develop this index. The B_{oi} index, often known as the buffer occupancy index, is defined as follows for any intermediate nodes:

$$B_{oi} = \frac{Total\ free\ space}{Total\ memory\ space} \times \tau (3)$$

Or,

$$B_{oi} - local = \frac{K_{local\ storage}}{M_{local\ storage}} \times \tau_{local} (4)$$

Where, τ= average processing time for one data packet

The formula for C in is provided by for an n-th number of intermediate storage nodes, each with congestion state m i

$$C_{in} = \sum_{i=0}^{n-1} B_{oi} - local + T_{B-to-B} P_{gdelay} (5)$$

If $'N_{hp}'$ is the number of hops between source and sink node, T_{Qd} as interface queue delay and per node per link delay of T_{pg} then B-to-B propagation delay is given by-

$$T_{B-to-B} P_{gdelay} = N_{hp} \times T_{pg} (6)$$

$$T_{pg} = T_{Qd} \times T_{MAC} \quad (7)$$

Or,

$$T_{Qd} = m_{i-interfac} \times \tau_{interface} (8)$$

T_{MAC} is given by-

$$T_{MAC} = T_{RTS/CTS} + T_{ch} (9)$$

Where, T_{MAC}= Access delay in MAC

$T_{RTS/CTS}$ = Latency due to ongoing transmission and

T_{ch}= Access delay of channel

So, congestion index C_{in}, can be now be expressed as-

$$C_{in} = \sum_{i=0}^{n-1} \frac{K_{local}}{M_{local}} \times \tau_{local} + \sum_{j=0}^{N_{h-1}} [\frac{K_{interface}}{M_{interface}} \times \tau + T_{RTS/CTS} + T_{ch}] (10)$$

This congestion index helpful in deciding the future rate adjustments for the source nodes.

3.2 Congestion detection

a technique based on the capacity of individual lines and intermediary nodes to assess the congestion of a network. Equation (10) is utilized to monitor the congestion state, which may then be used to estimate the new delay Tdelay for source nodes using the Mean Square method. By restricting it to Cin, the wait state for MAC level carrier detection may be avoided. As a result, using a joint density function is advised. This function builds a connection between the congestion index Cin and the B-to-B packet delay T_{delay}.

SIMULATION SETUP

We discussed the network architecture and the parameters used for testing CCTLP for WSN in this section of the article. The simulation setup's goals are to monitor the system's average throughput, average E-2-E delay, average data packet loss, average energy consumption per packet, and average system throughput.

Performance Metrics

The average data packet drop rate, average good throughput, average E-2-E data packet latency, and average energy use per packet are the metrics used to assess the CCTLP.

1) Better throughput

The definition of it is the percentage ratio of the total amount of data transmitted by all sources to the amount of data received by the sink.

$$\text{Throughput} = \frac{Total\ data\ sent}{Total\ data\ received} \times 100(11)$$

2) Average packet drop

It is defined as the % of the data loss between sent and received data to the sent data.

$$\text{Packet drop} = \frac{Total\ data\ sent - Tota\ \ data\ received}{Total\ sent\ dat} \times 100(12)$$

3) Average B-2-B packet delay

It is described as the whole time it would take for a package to travel from source to sink. This includes any delays that might arise from queuing and retransmission at the MAC layer.

$$T_{delay}(B-2-B) = (T_{received} - T_{send}) \times 1000msec(13)$$

4) Average per packet energy consumed

The average amount of energy used for each packet by the source, the delay, or the sink is expressed as a percentage of the overall energy used for packet processing.

$$Average\ energy = \frac{Total\ energy\ consumed}{Total\ packets} \times 100\ mJ \quad (14)$$

TOPOLOGY & NETWORK PARAMETERS

The network topology taken into account for assessing CCTLP is displayed in Fig. 2 below. Nodes 0 through 9 are thought of as source nodes, whereas nodes 11, 12, and 13 are thought of as intermediate storage nodes, and node 10 is thought of as a sink node.

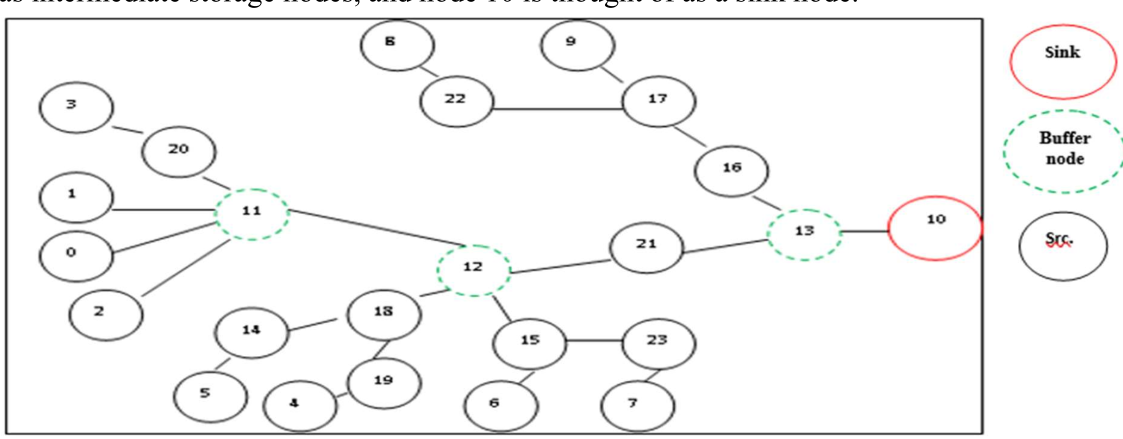

Fig. 2: Topology of network

The network parameter is shown in Table 2 also taking the source nature with their properties.

Table 2: Network parameters

Parameters	Values
Frequency (Hz)	$914e^{+6}$
Transport Protocols	CCTLP, TCP-WW+ [14], TCP-WW [15], TCP-NR [16], TCP-R [17]
MAC	IEEE 802.11 [18]
Rx and Threshold (W)	$2.65e^{-10}$ and $1.65e^{-11}$
Routing agent	Ad-hoc On-Demand Distance Vector (AODV) [19]
CP Threshold	10
Packets	50
Initial power (W)	50
Idle power (W)	$712e^{-6}$
Rx power (W)	$40.23e^{-3}$
Tx power (W)	$36.45e^{-3}$
Data Packet Size (Bytes)	256
SNR (threshold)	10
Sleep power (W)	0.002

SIMULATION RESULT & DISCUSSION

NS-3 (Network Simulator-3)is used as a simulator for testing and comparing the performance of CCTLP with TCP variants TCP-NR, TCP-WW, TCP-R and TCP-W++.

Average High Throughput Comparison

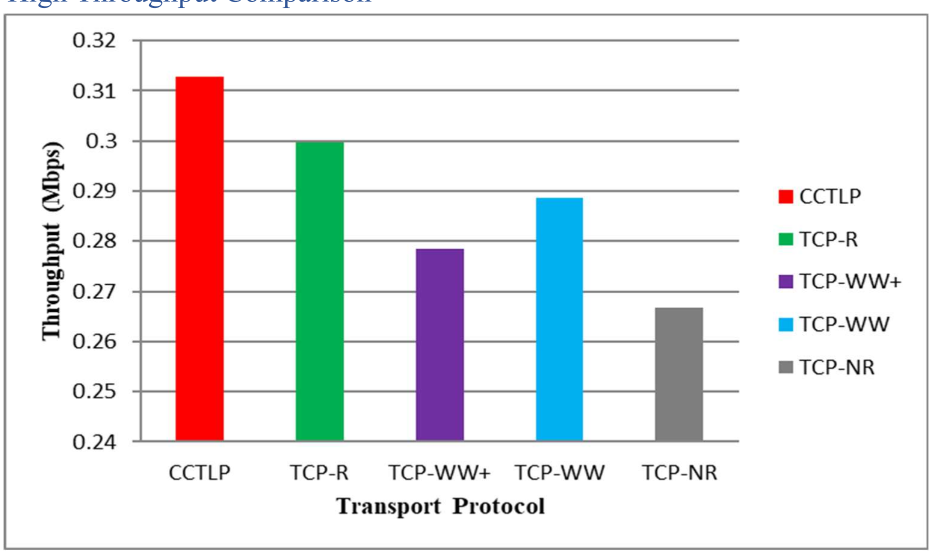

Fig. 3: Average B-2-B throughput comparison

The flow of traffic, including multimedia, together with the size of the packets was taken into consideration. In order to guarantee that the results are reliable, the simulation has been run more than five times, and the average values have been displayed.
Comparing the output of TCP-WW++, TCP-W, and TCP-NR, which are respectively 0.2784, 0.2886, and 0.2668 Mbps, we discover that CCTLP and TCP-R give a higher throughput, which is denoted by the values 0.3129 and 0.2998 Mbps in the figure that is located above. Because it is directly connected and uses a stochastically estimated value of T delay (a function of C in), the CCTLP is able to achieve a high throughput. CCTLP is essentially a sink-enabled B-2-B congestion control.

Average Packet Drop

A comparison of the average packet drop (B-2-B) statistics between CCTLP and the TCP variants TCP-NR, TCP-R, TCP-WW, and TCP-WW+ is shown in the following figure, Fig. 4. When compared to 3.74 percent, 3.26 percent, 2.63 percent, and 3.12 percent, the CCTLP displays around 0.36 percent less dropped packets than the other protocols do. Form Fig makes it very evident that CCTLP is the most reliable protocol for large packet volumes among all protocols. The most important reason for this is because its congestion management is dependent on real-time monitoring network data that offer a sense of how congested the network really is.

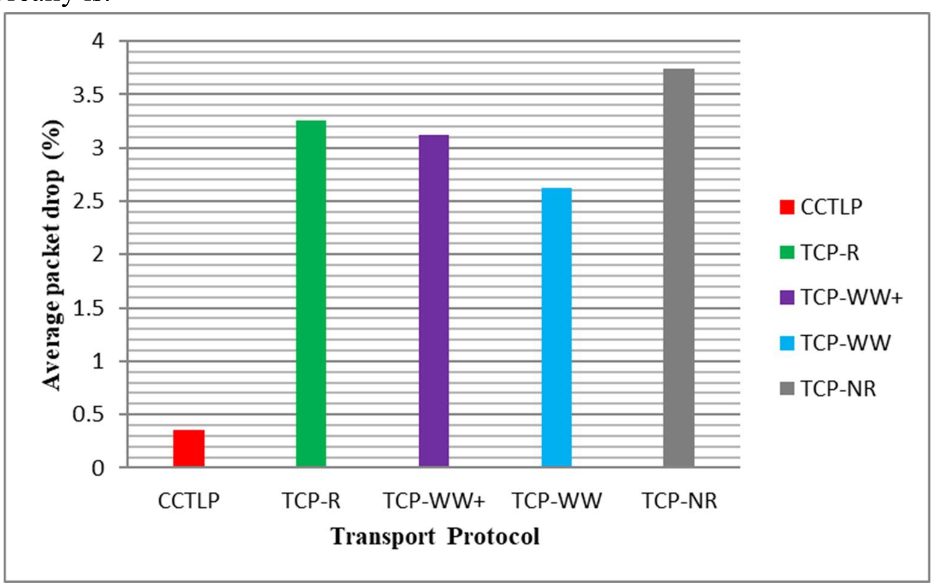

Fig. 4: B-2-B packet drop (%)

Average B-2-B Packet Latency

Fig. 5 the B-2-B data packet latency comparison of CCTLP with TCP-R, TCP-NR, TCP-WW+ and TCP-WW.

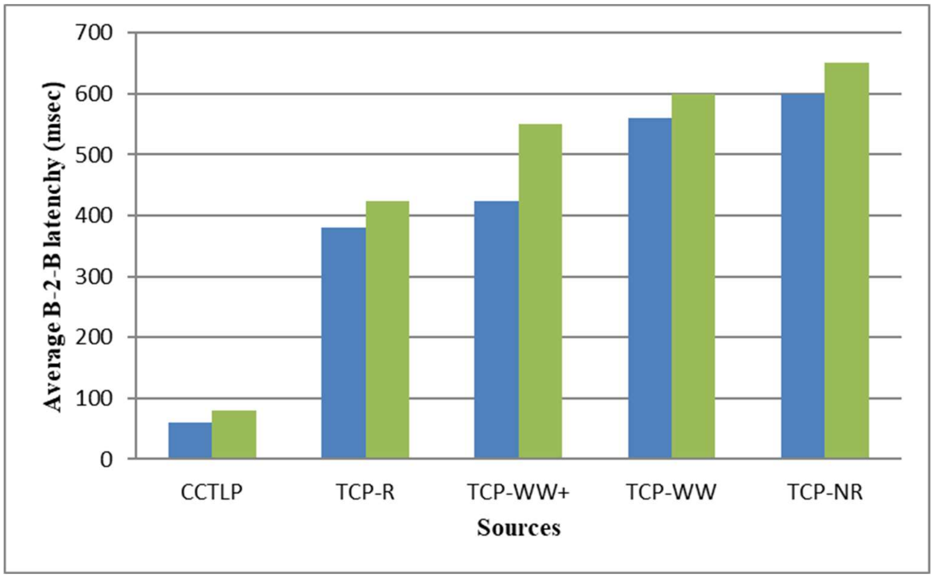

Fig. 5: Average B-2-B packet latency

This comparison makes it evident that the CCTLP is the best option since it uses real-time monitoring information of the data packet B-2-B delay related to the network congestion index. Packet information from sources used by TCP-WW and TCP-WW+ as transport agents, which examine the receiving acknowledgements for each sent data packet based on an estimate of BW, but experience a substantial degree of variable delay (560-650 msce).
When there are several hops between the source node and sink node, this variable delay falls between 380 and 550 milliseconds.The CCTLP, which has a comparable number of hops, has a packet delay that varies between 60 and 80 milliseconds. This includes the TCP versions TCP-R and TCP-NR. These results demonstrate a relationship between the rate adjustment approach and the use of the buffer occupancy of intermediate storage nodes and instantaneous network channel data, which combined comprise the B-2-B congestion index of the whole network. [20, 21].

Average Energy Consumed

Fig. 6 below shows the per packet energy consumed (in mJ) by the source, relay and sink nodes that uses different transport layer protocols.

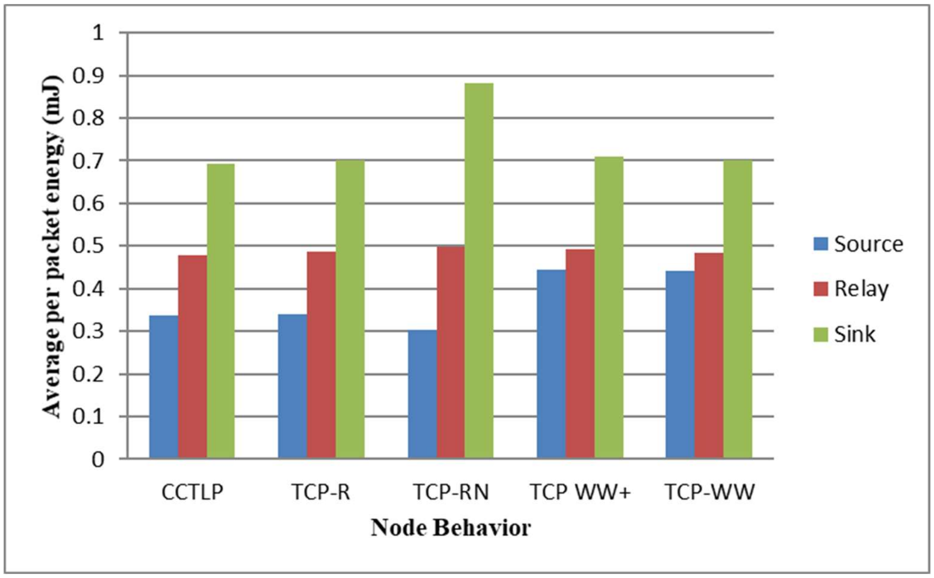

Fig. 6: Average per packet energy consumed

From the figure above, we can see that only CCTLP and TCP-R offer high throughputs of 0.3129 and 0.2886 Mbps, respectively, while the throughput offered by TCP-NR is the lowest of all transport layer protocols at 0.2668 Mbps. It is important to note that among all transport layer protocols, only CCTLP demonstrates an efficient behavior in terms of the amount of energy consumed per packet.

A CCTLP source node, relay node, and sink node, in that order, use 0.3365 mJ, 0.4794 mJ, and 0.6940 mJ of energy per packet. TCP-NR is the least efficient protocol since it has the lowest throughput of all the protocols and the lowest packet energy expenditure per source node (0.3026 mJ), but TCP-WW+, TCP-WW, and TCP-R spend the most energy overall (0.4476, 0.4420, and 0.4395 mJ, respectively). TCP-WW and TCP-WW+ have a large energy cost per packet because of their channel probing. Finally, we discover that TCP-R displays high per-packet energy consumption behaviour for source, relay, and sink nodes despite providing almost as excellent throughput as CCTLP.

CONCLUSION

Signal processing, control, and protocol design have all made attempts to address longevity, a critical design issue for WSNs. This may be accomplished by making sure that data dependability and congestion control are in place, both of which are crucial elements of any transport protocol design for WSN.

In this study, we present a congestion control protocol (CCTLP) that can identify congestion, alert it, change the source rate, and retrieve any data that could become available as a result of congestion or inadequate channel conditioning. For example, if a packet is dropped because of a high bit error rate or a collision at the receiver end due to transmission from a hidden node, the CCTLP would be able to detect and notify the congestion. It would also be able to adjust the source

We perform in-depth comparisons of the CCTLP against the TCP-WW, TCP-WW+, TCP-NR, and TCP-R protocols, and the findings show a considerable decrease in the B-2-B data packet delay. Additionally, the CCTLP and TCP-R both attain their best possible average excellent throughput. When compared to the other TCP variations, CCTLP demonstrates the most energy-efficient behaviour over the whole of the conversation. In addition, the findings indicate that the rate adaption mechanism stops large data packet loss. Therefore, the CCTLP performs admirably in contrast to all of the TCP variations that were taken into consideration, whether the network is crowded or not.

REFERENCES

[1] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "A survey on sensor networks," IEEE CommunicationsMagazine, vol. 40, no. 8, pp. 102–114, 2002.
[2] S. Meguerdichian, F. Koushanfar, G. Qu, and M. Potkonjak, "Exposure in wireless ad-hoc sensor networks," in Proceeding of the 7th Annual International Conference on Mobile Computing and Networking, pp. 139–150, July 2001.
[3] C. Wang, K. Sohraby, B. Li, M. Daneshmand, and Y. Hu, "A survey of transport protocols for wireless sensor networks," IEEE Network, vol. 20, no. 3, pp. 34–40, 2006.
[4] J. Postel, "Transmission control protocol," Tech. Rep. RFC- 793, Information Sciences Institute, 1981
[5] J. Postel, "User datagram protocol," Tech. Rep. RFC-768, Information Sciences Institute, 1980.
[6] I. F. Akyildiz, T. Melodia, and K. R. Chowdhury, A survey on wireless multimedia sensor networks, Comput. Netw., 51, pp. 921–960, 2007
[7] V. Gungor and O. Akan, Dst: delay sensitive transport in wireless sensor networks, in International Symposium on Computer Networks, pp. 116 –122, 2006.
[8] S. Kim, R. Fonseca, P. Dutta, A. Tavakoli, D. Culler, P. Levis, S. Shenker, and I. Stoica, Flush: a reliable bulk transport protocol for multihop wireless networks, in SenSys '07: Proceedings of the 5th international conference on Embedded networked sensor systems, New York, NY, USA, ACM, pp. 351–365, 2007.
[9] Y. Zhou, M. Lyu, J. Liu, and H. Wang, Port: a price-oriented reliable transport protocol for wireless sensor networks, pp. 117 –126, 2005
[10] E. Giancoli, F. Jabour, and A. Pedroza, Ctcp: Reliable transport control protocol for sensor networks, in International Conference on Intelligent Sensors, Sensor Networks and Information Processing, ISSNIP, pp. 493 –498, 2008
[11] N. Tezcan and W. Wang, Art; an asymmetric and reliable transport mechanism for wireless sensor networks, Int. J. Sen. Netw., , pp. 188–200, 2007.
[12] J. Paek and R. Govindan, Rcrt: rate-controlled reliable transport for wireless sensor networks, in SenSys '07: Proceedings of the 5th international conference on Embedded networked sensor systems, New York, NY, USA, ACM, pp. 305–319, 2007.

[13] V. C. Gungor, O. B. Akan, and I. F. Akyildiz, A real-time and reliable transport (rt) 2 protocol for wireless sensor and actor networks, IEEE/ACM Trans. Netw., pp. 359–370, 2008.
[14] Tcpwestwood+, http://c3lab.poliba.it/index.php/westwood, 2008.
[15] C. Casetti, M. Gerla, S. Mascolo, M. Y. Sanadidi, and R. Wang, Tcpwestwood: end-to-end congestion control for wired/wireless networks, Wirel. Netw., 8, pp. 467–479, 2008
[16] Tcp new reno, http://www.faqs.org/rfcs/rfc3782.html, 2008.
[17] Tcp reno, http://tools.ietf.org/html/rfc1644, 2008.
[18] Ieee p802.11, main general info page.
[19] C. Perkins, E. Royer, and S. Das, Ad hoc on-demand distance vector (aodv) routing rfc 3561,2003.
[20] E. D. Siegel, Applications and infrastructure issues, Wiley Computer Publishing John Wiley & sons.
[21] How delay and packet loss impact voice quality in voip, 2008.