PERFORMANCE of DATAGRAM CONGESTION CONTROL PROTOCOL DCCP-TCP-LIKE and DCCP-TFRC on SENSOR NETWORK

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***Abstract*—Congestion control, managing reliable data transmission between a source and destination, is a major issue in all kinds of networks. In case of structured networks the presently available algorithms provide satisfactory performance, where as the performance is inferior with high density *Wireless Sensor Networks* (WSN), due to the underlying techniques. In this paper it is attempted to identify the most suitable transport protocol among the selected available protocols, *viz. DCCP TCP Like Congestion Control* (DCCP_TCPLike) and *DCCP TCP Friendly Congestion Control* (DCCP_TFRC), by estimating their performance with respect to certain suitable metrics. The congestion scenario is simulated for both the protocols and their performances are evaluated on Network Simulator (NS2) and analyzed based on the selected metrics. It is found that the performance of DCCP_TFRC based protocol is better and more suitable than its counterpart considered in this work.**

Keywords- Congestion Control, Transport Protocols, Sensor Network, TCP, UDP, SCTP, DCCP.

I. INTRODUCTION

A. *The Wireless Sensor Network (WSN)*

A wireless sensor network is a wireless network consisting of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants, at different locations [1]. Each device in a sensor network is called as *Node* and each node is normally equipped with wireless communication device, typically a radio transceiver, a microcontroller to channelize the functions of the sensor, and an energy source, usually a battery. The selection of memory size, computational speed, bandwidth, energy and the like are restricted mainly by the cost and size of the nodes.

In general, wireless sensor network transmission is multi-hop nature and constituted by energy constrained nodes. Since the sensors are usually small and inexpensive and have limited energy sources, any protocols to be deployed in sensor networks need to be aware of energy usage. The data to be transmitted by a sensor node is in the form of packet and the network is equipped with an appropriate routing mechanism that can adapt to the network dynamics. From the viewpoint of a transport protocol, the underneath network is an IP based full functional network. To assure a data packet to be delivered to the destination reliably, a transport layer protocol must be embedded between application and network layer.

High data rate applications involve voluminous data transfer and require a more reliable transmission and hence, persistent congestion may occur[2]. In such high rate sensor network applications a fairly reliable solution is mandatory to avoid congestion and to maintain complete and efficient data transfer between many sources and one or more sinks [3].

The paper is organized in the following manner. Next section discusses the necessity of this work in the present scenario. Chapter II gives an overview of the transport protocols considered paper *viz*. TCP, UDP and SCTP and an overview on congestion control. Chapter III details the model of WSN considered in this work and the metrics considered to evaluate the performance of the WSN. The simulated responses of the WSN with its parameters set to the values discussed in Chapter III, in terms of the metrics considered in this work, for all the three different protocols, along with an exhaustive analysis, are given in Chapter IV. Chapter V discusses the inferences arrived out of the analysis.

B. *Need of this work*

A typical wireless sensor network is highly unstable as it is error-prone due to various reasons such as interference of radio signal, radio channel contention, and survival rate of nodes [4]. This error rate is increased significantly in a multi-hop network due to channel contention. Further, in a sensor network error rate is much higher and bandwidth is smaller than that of fixed networks. As a consequence, running conventional protocols like Transport Control Protocol (TCP), Stream Control Transmission Protocol (SCTP) etc., on a wireless sensor network will potentially suffer from severe performance degradation.

It is obvious that the capabilities of wireless sensor nodes are much less than that of their fixed network counterparts, due to various reasons[5]. The complexity in implementing standard protocols inside the tiny sensor nodes further degrades the performance of wireless nodes. However, the capabilities of the modern sensor nodes have improved so much to accommodate a fully functional TCP like protocol inside them. The comparatively new protocol DCCP is having interesting properties, which makes it possible to use it in an error-prone sensor network scenario. To evaluate the performance of DCCP, when implemented over a congested WSN, it is necessary to conduct experiments with under various environmental conditions. In this work the traffic density or number of packets transmitted over the given time intervals is considered and the performance is evaluated with respect to throughput, end-to-end (E2E) delay, MAC load, routing load and packet loss with an intention to propose a better congestion control algorithm for sensor networking.

II. THE TRANSPORT PROTOCOLS AND CONGESTION CONTROL

A. Transport Layer

The main objective of the transport layer is to provide reliable and controllable end-to-end communication service for applications with connection-oriented data stream support. Though the transport protocols, such as TCP, work efficiently in infrastructure networks, their performance is relatively poor when employed in wireless sensor networks, hence require considerable modifications [6]. As TCP is strictly end-to-end reliability model, confirmations and retransmissions, if any, need to follow the complete source-to-destination path, resulting in inefficient use of bandwidth along with energy burden on already energy hungry nodes. The transport protocols proposed so far deal either optimization of a particular parameter or application specific. It is desirable to design a transport layer protocol that can support multiple applications in the same network, provide controlled variable reliability, address congestion issues, reduce latency and maximize throughput [2].

B. Congestion Control

Congestion, transmitting packets beyond the admissible limit of a link, may not be constant over the different points of the WSN, due to its multi-hop nature and a different degree of congestion might be felt at different points over WSN [7]. It is obvious that the congestion is high around the base station or 'sink', due to the convergent nature of the traffic towards the base station. This huge amount of data flow, along with the constrained buffer size, results in congestion, which may lead to a significant amount of packet loss or data loss. This further necessitates packet retransmission and causes a significant amount of energy loss and delivery delay. High data rates, sudden burst of data and collisions are other reasons of congestion in sensor networks

Congestion may be sensed by buffer drops and increased delays in traditional networks and researchers have developed end-to-end adaption and network layer dropping or signaling techniques to prevent the network from collapsing due to congestion, over period of time. In addition to buffer overflows, the quality of the WSN is degraded mainly due to the excessive traffic over the radio channel as those channels are not insulated from each other as in the case of wired or provisioned cellular links, resulting in the degradation of the channel quality. The quality of the network is further deteriorated by poor and time varying channel quality, asymmetric communication channels, multi-hop environment etc., [8].

Congestion detection, congestion notification and rate-adjusting are the three major phases of Congestion control. The main performance objective of a congestion control protocol is energy efficiency which is achieved by minimizing or avoiding packet loss due to buffer overflow and assuring prolonged life time for the system. Maintaining a fairly reasonable throughput in each node by rate-adjustment *i.e.* the rate at which the sensors send data to sink node, and packet scheduling is the another major objective of congestion control protocols. Another desirable characteristic of congestion control protocols is to provide a better Quality of Service (QoS) in terms of packet loss ratio, packet delay, throughput etc., [9]. Hence, it is required not only to detect the congestion but also to implement an appropriate avoidance technique to minimize losses and to increase the overall performance of WSN.

C. Datagram Congestion Control Protocol (DCCP)

With User Datagram Protocol (UDP) as the base, DCCP is developed for effective and efficient handling of congestion over WSN resulting in more reliable transmission of datagram or packets.

It is highly promising that DCCP will become the de facto standard for multimedia rich content delivery over IP-based networks [10].

This protocol is suitable for the applications where the timely data transmission of data is more important than the overall consistency. Hence, the flow of datagrams may be unreliable but with acknowledgements.

In the initial phase three-way handshaking mechanism is implemented in this protocol which permits servers to get rid of the holding state for the unacknowledged connections and already-finished connections and hence, termed as reliable handshakes for connection setup and teardown.

In computing the modifications to the transmission rate, congestion control incorporating Explicit Congestion

Notification (ECN) and ECN Nonce are used where the ECN marked packets are treated as if they are dropped packets.

The main objective of DCCP is to extend support for implementing different congestion control schemas out of which the most apt one may be selected by the applications, particularly multimedia streams, so as to provide efficient congestion control. Hence, according to the type of data being transmitted a schema will be selected to assure a better flow of packets.

A mechanism, known as Congestion Control Identification (CCID), is implemented in DCCP, enabling it to assign separate CCID for each direction of data flow. CCID defines the nature of congestion control mechanism and the selection of appropriate mechanism by the source and destination is achieved by the so called feature-negotiation [12]. DCCP congestion control structure is so designed that the addition of new congestion control algorithms or the deletion of existing algorithms takes place, regardless of the core of the protocol. DCCP TCP Like Congestion Control (DCCP_TCPlike) and DCCP TCP Friendly Congestion Control (DCCP_TFRC) are two such standard mechanism available as of now.

D. DCCP TCP Like Congestion Control (DCCP_TCPlike)

TCP Like Congestion Control (CCID 2) implements congestion control through tracking a transmission window, and regulating the transmit rate similarly to TCP. CCID 2 is suitable for senders who can adapt to the abrupt changes in congestion window typical of TCP’s Additive Increase Multiplicative Decrease (AIMD) congestion control, and particularly useful for senders who would like to take advantage of the available bandwidth in an environment with rapidly changing conditions [13]. CCID 2, TCP-like Congestion Control, is appropriate for DCCP flows that would like to receive as much bandwidth as possible over the long term, consistent with the use of end-to-end congestion control. CCID 2 flows must also tolerate the large sending rate variations characteristic of AIMD congestion control, including halving of the congestion window in response to a congestion event. Applications that simply need to transfer as much data as possible in as short a time as possible should use CCID 2.

E. DCCP TCP Friendly Congestion Control (DCCP_TFRC)

TCP Friendly Congestion Control (TFRC) (CCID 3) implements congestion control by tracking the rate at which packets are lost (but at most one packet per round trip time), and varies the transmit rate in a smoother manner, using additive increases and subtractive decreases. TFRC is a receiver-based congestion control mechanism that provides a TCP-friendly sending rate while minimizing the abrupt rate changes characteristic of TCP or of TCP-like congestion control. The sender's allowed sending rate is set in response to the loss event rate, which is typically reported by the receiver to the sender[14]. CCID 3's TFRC congestion control is appropriate for flows that would prefer to minimize abrupt changes in the sending rate, including streaming media applications with small or moderate receiver buffering before playback.

III. THE SIMULATION OF SENSOR NETWORK

Network Simulator – 2 (NS2) is the tool used to simulate the proposed WSN and preset values of two of the default parameters are so selected that the breaks in periodic reporting of sensor data are avoided. *Maximum retransmit time-out* is the first parameter and the *Time-out* parameter in the *respond-state* is the second one. These parameters are set to 5 sec instead of preset 75 sec, for the reason stated above. Table 1 presents the parameters and the values selected for them in this work.

TABLE 1 : PARAMETERS OF THE SENSOR NODE AND NETWORK

Parameter		VALUE
Transmission Range		
Sink Node	:	**150 m**
Sensor Node 1 to 7	:	**150 m**
Other Sensor Nodes	:	**60 m**
Channel	:	**Wireless Channel**
Propagation	:	**Two Ray Ground**
Physical Medium	:	**Wireless Physical**
Antenna	:	**Omni Antenna**
Routing Protocol	:	**AODV**
Mac Type	:	**802.11**
Queue	:	**DropTail/PriQueue**
Queue Size	:	**50**
Sensor Reporting Interval	:	**1, 2, 5, 10a nd 20 sec**
Traffic Application	:	**CBR**
Sensor Data Size	:	**256 bytes**
Number of Nodes	:	**56**
Topographical Area	:	**800m x 400m**
Transport Protocols	:	DCCP_TCPLIKE **and DCCP_TFRC**
Simulation Time	:	**100 sec**
Node Receiving Threshold	:	**3.652e-10**
Node Signal Frequency	:	**2.4e09 Hz**

The simulated distribution of the nodes, which is highly random, is shown in Figure 1. The Nodes 1 to 7 are the gateway nodes through which all other normal sensor nodes communiate to Sink node, designated as Node-0. The transmission range of gateway nodes and sink node are set to 150 m, higher than that of other normal sensor nodes.As MICA mote is widely used, particularly by Researchers and Developers, the characteristics of the normal sensor nodes are so chosen to emulate the real nodes and hence a much better practical WSN scenario is attempted.

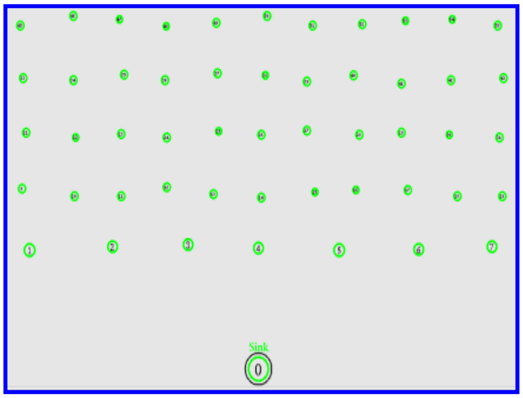

Fig 1 : The Wireless Sensor Network

A. Metrics considered for Evaluation

1) *Throughput :* The rate of data packet arrival with respect to time at the destination or sink is the throughput of the network and hence, higher the rate is better the congestion control algorithm.
2) *Energy Consumption :* The average energy consumed by all the nodes of the network is considered as a metric to assess the performance of the congestion control algorithms. The energy consumption of a node depends on several parameters such assensor data reporting interval, routing protocol, transport protocol, congestion algorithm of the transport protocol etc., and it is obvious that the lower energy consumption signifies better congestion control algorithm.
3) *Routing Load :* It is the number of routing packets required to transmit a data packet successfully to the sink node. A better congestion algorithm provides a relatively lower routing load for the given data packet.

IV. THE RESULTS AND ANALYSIS

The WSN with DCCP_TCPLike and DCCP_TFRC protocols for the scenario discussed in section II with different data reporting intervals have been simulated and results obtained are plotted with respect to the selected metrics. The performance analyses of WSN with respect to each of the metrics considered in this work are as follows.

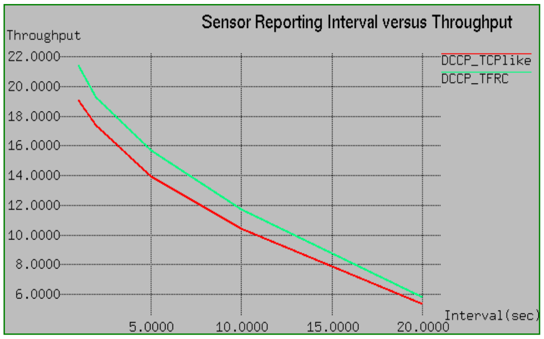

Figure 2 : Throughput with respect to Different Data Interval

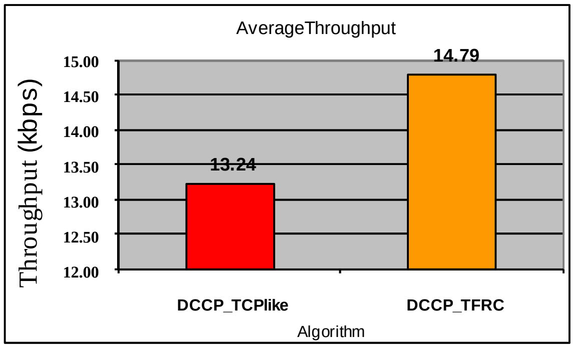

Figure 3 : The Average Throughput

Figure 4 shows the energy consumed in Joules for the two protocols at different time intervals. It may be observed that there is sudden rise and fall during low data reporting intervals and almost constant energy consumption over high data reporting intervals, as far as DCCP_TFRC protocol is considered. On the other hand there is relatively a lesser fluctuation in the energy consumption with respect to DCCP_TCPLike protocol, over the period of time. However, the average energy consumption with respect to the two protocols is almost same, as shown in Figure 5.

The throughput with respect to the two protocols over the selected period time is given in Figure 2. It is may be observed from the plot that the throughput is better during low data reporting interval than that of during higher data intervals for both the protocols. It may also be noticed that DCCP_TFRC is having an edge over DCCP_TCPLike throughout the entire time period and this fact is evident when the average throughput is taken in to account during the same period as shown in Figure 3.

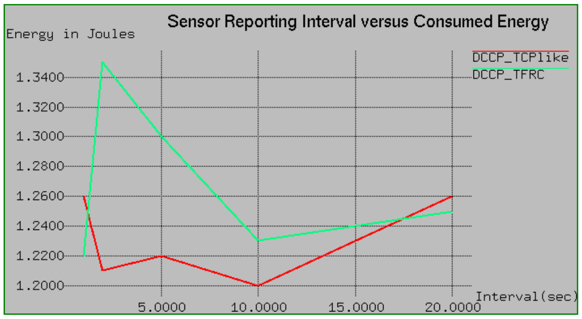

Figure 4 : Consumed Energy with respect to Different Data

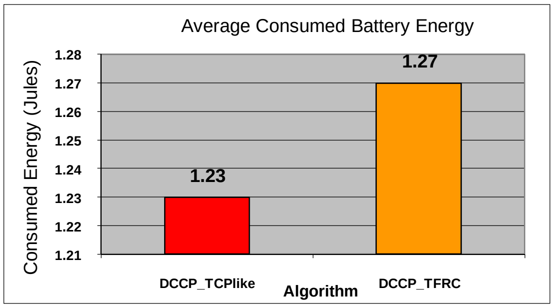

Figure 5 : The Average Consumed Energy

The performance with respect to routing load metric is given in Figure 6 and it may be noticed that at low data intervals it is almost constant and same for both the protocols. As the time interval increases, the routing load also increases linearly for both DCCP_TCPLike and DCCP_TFRC based WSNs with a better loading effect in case of latter. From Figure 6 it may also be inferred that there may not be much deviation between the average loading effects of the two protocols and this fact is substantiated by the plot given in Figure 7, which connects the average routing load and data interval time.

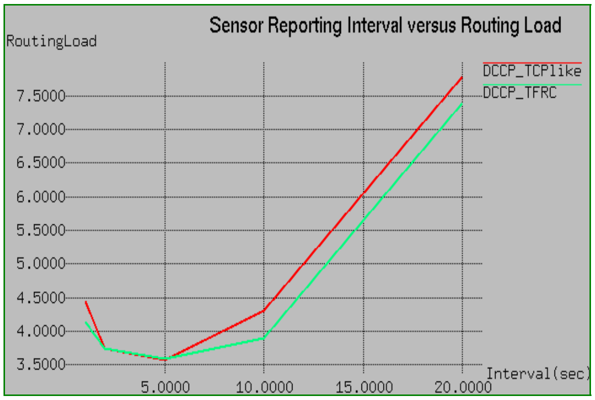

Figure 6 : Routing Load with respect to Different Data Interval

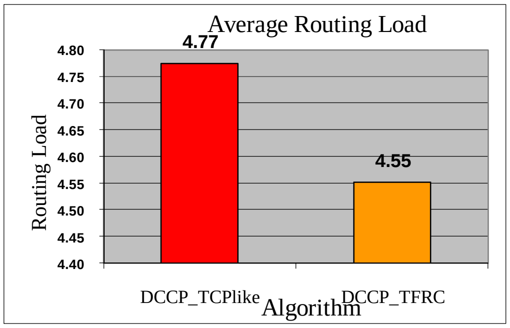

Figure 7 : The Average Routing Load

The performances of the WSNs with respect to the metric MAC load are given in Figure 9 and Figure 10. Here too the performances of the WSNs with the proposed protocols are constant and equal at low data intervals and exhibit linear rise as the data interval increases, similar to that of routing load metric, resulting in negligible difference among the average loads.

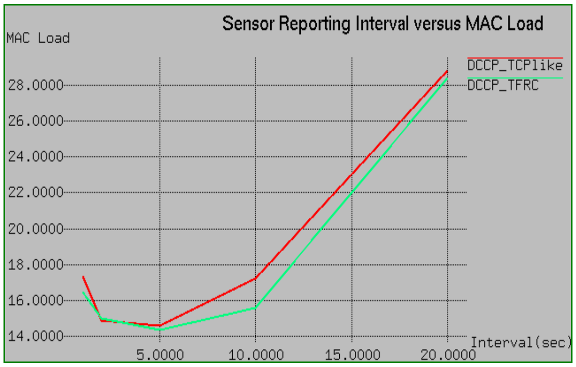

Figure 8 : Mac Load with respect to Different Data Interval

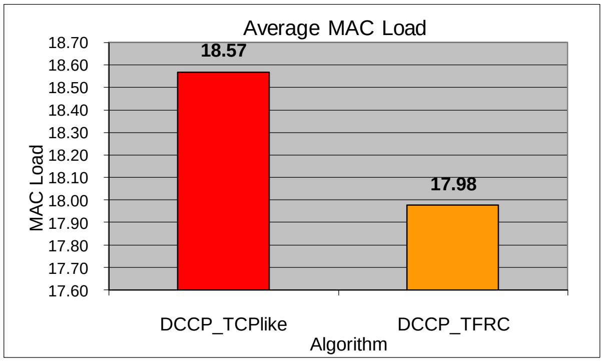

Figure 9 : The Average MAC Load

Figure 10 shows the variation in the number of dropped packets with respect to data reporting interval time. It is found that number of dropped packets, which are high atvery low data report intervals, falls drastically within a short period of time and then again increases gradually as the data report time increases. Hence, it may be inferred that the number of dropped packets is lesser at reasonably low data reporting intervals and increases with the data reporting interval. It may also be noticed that DCCP_TFRC protocol based systems always exhibit a relatively low loss of data packets and the rate of increase in the loss is higher in case of DCCP_TCPLike protocol based WSNs than that of DCCP_TFRC based ones. The higher value in the average data packet loss in case of DCCP_TCPLike is evident as shown in Figure 11.

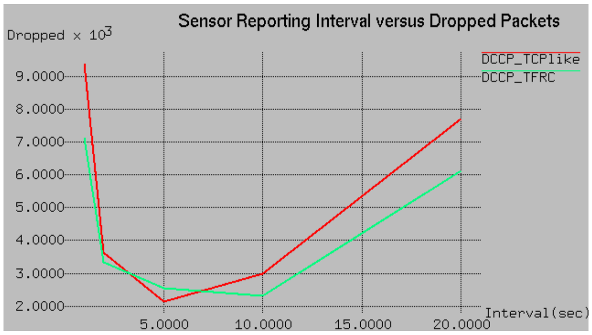

Figure 10 : Packets Dropped with respect to Different Data Interval

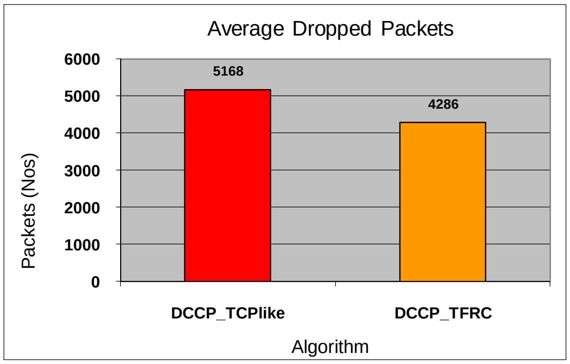

Figure 11 : The Average Dropped Packets

The changes in the metric E2E Delay is as shown in Figure 12. Here too the change in E2E delay is similar to that of dropped packets, wherein the delay falls at a faster rate at the very beginning and increases linearly at a relatively lower rate as the data reporting time increase for both the protocols without any appreciable difference among them. Figure 13, which shows the average delay, over the time period considered, is almost same for both the protocols, with DCCP_TCPLike having an edge over its counterpart.

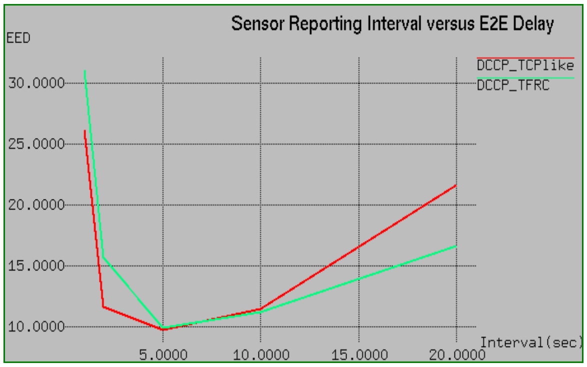

Figure 12 : The End to End Delay with respect to Different Data Interval

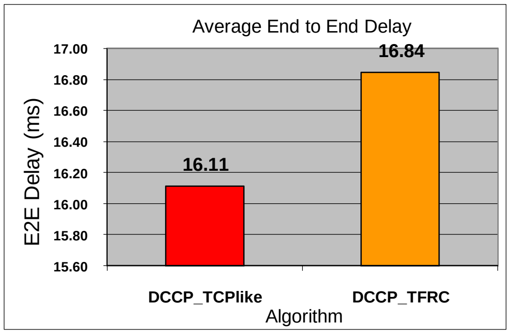

Figure 13 : The Average End to End Delay

V. CONCLUSION

The WSNs based on DCCP_TFRC protocol and DCCP_TCPLike protocols have been successfully simulated in NS2 and the congestion control behavior of the sensor networks with respect to the six metrics considered in this work has been plotted with respect to a range of data reporting intervals. Exhaustive analyses on the results have also been made. It is found that the DCCP_TFRC protocol based networks consume more power during low data reporting intervals and improves with high data reporting intervals whereas in DCCP_TCPLike protocol based networks the power consumption is low during low data intervals and increases linearly with the data reporting intervals and hence, DCCP_TCPLike is suitable if the battery life is the main criterion. On the other hand the performance of DCCP_TFRC based sensor networks perform better with respect to all other metrics considered in this work though the margin is slender. Hence, it may be concluded that, barring the power consumption at low data reporting intervals, the sensor networks based on DCCP_TFRC protocol is having an edge over DCCP_TCPLike protocol based sensor networks.

VI. ANNEXURE

Tables Results of the Performance of Different Algorithms

The following table shows the performance of UCCP-TCPlike with different metrics at different sensor data reporting intervals.

TABLE 2 : PERFORMANCE OF DCCP-TCP_LIKE

Data Interval	E2E Delay	Routing Load	MAC Load	Dropped Packets	Throughput	Consumed Power
1	26.12	4.45	17.32	9369	19.05	1.26
2	11.61	3.75	14.90	3633	17.39	1.21
5	9.73	3.58	14.61	2147	13.92	1.22
10	11.46	4.31	17.24	2990	10.46	1.20
20	21.64	7.78	28.77	7700	5.38	1.26
Avg	16.11	4.77	18.57	5168	13.24	1.23

The following table shows the performance of UCCP-TFRC with different metrics at different sensor data reporting intervals.

TABLE 2 : PERFORMANCE OF DCCP-TFRC

Data Interval	E2E Delay	Routing Load	MAC Load	Dropped Packets	Throughput	Consumed Power
1	30.97	4.13	16.46	7113	21.40	1.22
2	15.63	3.74	15.03	3340	19.30	1.35
5	9.86	3.59	14.39	2544	15.72	1.30
10	11.14	3.90	15.60	2316	11.76	1.23
20	16.62	7.40	28.40	6117	5.79	1.25
Avg	16.84	4.55	17.98	4286	14.79	1.27

VII. REFERENCES

[1]. Jang-Ping Sheu, Li-Jen Chang and Wei-Kai Hu, “Hybrid Congestion Control Protocol in Wireless Sensor Networks”, Journal Of Information Science And Engineering 25, pp. 1103-1119, 2009

[2]. Y. G. Iyer, S. Gandham, S. Venkatesan, “STCP: a generic transport layer protocol for wireless sensor networks”, 14th International Conference on In Computer Communications and Networks, pp. 449-454,2005.

[3]. Alam and Hong, “Congestion-Aware and Rate-Controlled Reliable Transport in WSNS”, The Institute of Electronics, Information and Communication Engineers, 2009.

[4]. Yao-Nan Lien, "Hop-by-Hop TCP for Sensor Networks", International Journal of Computer Networks & Communications - IJCNC, Vol.1, No.1, April 2009.

[5]. Jang-Ping Sheu1, Li-Jen Chang And Wei-Kai Hu, “Hybrid Congestion Control Protocol in Wireless Sensor Networks”, Journal of information science and engineering 25, 1103-1119,2009

[6]. Paulo Rogério Pereira, *et.al.*, “End-To-End Reliability in Wireless Sensor Networks: Survey and Research Challenges”, EuroFGI Workshop on IP QoS and Traffic Control P. Pereira (Ed.)’ Lisbon, Portugal, December 6-7, 2007.

[7]. Md. Abdur Rahman, Abdulmotaleb El Saddik and Wail Gueaieb, “Wireless Sensor Network Transport Layer: State of the Art”, S.C. Mukhopadhyay, R.Y.M. Huang (eds.), Sensors, 221,c_ Springer-Verlag Berlin Heidelberg , 2008

[8]. B. Hull, K. Jamieson, and H. Balakrishnan, “Mitigating congestion in Wireless Sensor Networks”, SenSys ’04: Proc. 2nd International Conference on Embedded Networked Sensor Systems, pp.134–147, ACM, 2004.

[9]. Chonggang Wang1, Kazem Sohraby, Victor Lawrence, Bo Li, Yueming Hu, “Priority-Based Congestion Control in Wireless Sensor Networks”, Proceedings of the IEEE International Conference on Sensor Networks, Ubiquitous, and Trustworthy Computing - SUTC’06, 2006.

[10]. D StanimirStatev, SeferinMirtchev, "Experimental Study of DCCP Transport Protocol in Varied Network States", International Scientific Conference Computer Science' 2008.

[11]. Leandro Melo de Sales, Hyggo Oliveira, Angelo Perkusich, ArnaldoCarvalho de Melo, "Measuring DCCP for Linux against TCP and UDP With Wireless Mobile Devices", 2008 Linux Symposium, Volume Two.

[12]. Kohler E., S. Floyd, and M. Handley, "Designing DCCP: Congestion Control without Reliability," in Proc. ACM SIGCOMM, Pisa, Italy, 2006

[13]. Floyd S. and E. Kohler, "Profile for Datagram Congestion Control Protocol (DCCP) Congestion Control ID 2: TCP-like Congestion Control," RFC 4341 (Pro- posed Standard), Mar. 2006.

[14]. Floyd S., E. Kohler, and J. Padhye, "Profile for Datagram Congestion Control Protocol (DCCP) Congestion Control ID 3: TCP-Friendly Rate Control (TFRC)," RFC 4342 (Proposed Standard), Mar. 2006.

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