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Hierarchy Based Compressive Sensing and Congestion Aware Routing Protocol for Wireless Sensor Network

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Abstract

Generally sensor nodes are equipped with competence of sensing different kinds of physical and environmental conditions, data processing, and wireless communication. Congestion in wireless sensor networks (WSNs) is a vital problem. Packet loss, delay and extreme energy consumption will lead while congestion occurs. However, the characteristics of wireless sensor networks necessitate effective methodology to optimize the traditional parameters. In this paper we propose (TAR) Traffic Aware Routing based on Hierarchical approach; this approach breaks the networks into energy aware clustered layer. Wavelet based compressive sensing also applied for the purpose of speeding up the synchronization process.

Keywords: *Wireless Sensor Network, Congestion control, Traffic aware routing.*

1. Introduction

Nowadays, WSN network is supports the accessibility of small and low-cost sensor nodes with capability of sensing different kinds of data processing, and wireless communication. Typically sensor nodes have limitations on the following area;

a) Amount of energy and memory storage
b) Transmission range,
c) Processing capabilities.

Those sensor node's sense data from the source region and communicate with nearby nodes to reach the Base Station or Sink by the wireless manner. The rapid proliferation of WSN, as a result most of the crucial department functioning based on WSN network including military application to modern health care.

Basically, Congestion phenomenon is the conventional obstacle for both wireless and wired network communication. This is why we concentrate a lot for congestion avoidance is crucial part for heterogeneous WSN network. As per the goal of transmit data packets from a source region to BS in heterogeneous environment.

There is significant interest by the researchers in mounting better radios, MACs, and distributed control algorithms [17] able to enhance the performance of the networks enabled them to operate in a stable manner under varying workloads while delivering suitable application loyalty.

In this paper, we consider a wireless sensor network were organized nodes are heterogeneous according to their characteristics and roles; they cause traffic intended to the BS. According to conventional approach of formation of cluster among scattered nodes will lead to energy efficient communication for WSN network. Amount of energy dissipation is directionally proportional to sensing distance between the nodes. Hence, it is necessary to build two-tier architecture between the sensor node and BS (Base Station). We do tier classification based on sensing distance based threshold parameter. The rest of the paper is organized as follows: Section 2 states that some related works based on congestion avoidance. Section 3.1 presents wavelet based compressive sensing approach. Threshold based 2-tier communication methodology described in section 3.2. Before concluding the paper work in section5, we present's simulation results, it illustrates the efficiency of HCSCAP protocol in section 4.

2. Related Works

B. Radunovi et.al [2] developed a novel system, which one is based on multi-path forwarding in wireless mesh network. Proposed framework works fine with both unmodified TCP stack and 802.11 MAC standards. They perfectly exemplify the modified version of back pressure approach. It also manipulates the delayed recording algorithm to tackle the timeout issue.

P.Key et.al [3] investigated on a session coupled rate control over multi-path performance analysis. Specifically, they studied lot on the following area

1) Data transfers under two classes of multipath control
2) Coordinated control where the rates over the paths are determined as a function of all paths.
3) Uncoordinated control where the rates are determined independently over each path.

Akyildiz, S et.al conducted a survey based on current trends of issues among several applications in WSN network and categorized into appropriate features [8]. As per the Akyildiz survey report, ongoing attention for this investigation area is passionate one. Analysis of those recent application & trends report, utilized for develop an efficient application or research problem over wireless sensor network. B.krishnamachari, and v. k. prasanna presented a literature [4] based on tradeoffs in the context of data gathering in WSN network. As per the proposed work, transmission energy and transmission delay are plays such a major role. And their objective function jointly adjusts the data aggregation and energy parameter with respect to acceptable latency constraint. Ramakrishnan, K and Jain Raj invented connectionless protocol [5] perform congestion avoidance by network layer optimization. Whenever router detects the congestion occurrence, then router injected a bit over the regarding packet. The congestion indication is communicated back to the users through the transport-level acknowledgment. By this way they intuitively avoided the congestion occurrence. I. Rhee et.al presented a light weight hybrid protocol named Bin-MAC (Binary Medium Access control) [6] for payload based resource constrained wireless sensor nodes. Bin-MAC's peculiar feature is its deterministic contention resolution mechanism, which facilitates to attain bounded latency on information transmissions. And this protocol is applicable to delay-sensitive applications with real-time constraints, a feature not provide by most of the existing hybrid protocols. Generally WSN network proficient platform to develop different kinds of surveillance application. For example B. Son et.al developed a FFSS [7] (forest-fires surveillance system) in South Korea Mountains. Here developed system protects the precious natural resources during dry winter season. Existing surveillance systems based on camera, infrared sensor system and satellite system. D. M. Doolin and N. Sitar presented one of the crucial application uses of wireless sensor network for real-time forest fire detection [9]. This framework always delivered an accurate detection of forest fire danger rate among conventional surveillance approaches. It performs the data acquisition in dynamic manner at the time of data collection process. According to high level architectural aspect, MAC and transmission control protocols are decisive enabling technology for many sensor network applications. Alec Woo and David E studied the problem of media access control in the novel regime of WSN network. They proposed an adaptive rate control mechanism [11] aiming to support both the energy budget as well as high level bandwidth aggregation. Above two constrains are most important factors of Media Access Control protocol. Philip Levis et.al presented Trickle [12] an algorithm for propagating and maintaining code updates in WSN network. They proved with this simple methodology, Trickle can scale to thousand-fold changes in network density. One major challenge is that sensor networks exhibit a unique funneling consequence where events delivered under varying workloads move quickly towards the BS. Some literature directed towards the multiple sink and Virtual sink approaches to minimize the congestion occurrence. Chieh and B. Eisenman proposed to utilize the accessibility of a tiny number of all wireless [13], multi-radio virtual sinks that can be randomly distributed or selectively placed across the field area.

3. Proposed Work

In this section we describe our proposed methodology. According to our congestion aware protocol, major key points are listed below:

a) Event based data gathering in wavelet based compressive manner.
b) Specifically we extend the entire network life time by tier classification among scattered nodes.
c) Our framework also increases the average sleep time of every node. Here, we illustrate Hierarchy Based Compressive Sensing and Congestion Aware Routing Protocol (HCSCAP) in detail to tackle the issues of congestion detection and avoidance.

3.1 Wavelet based compressive sensing

Compressive sensing [15], [16] is a compilation of recently proposed sampling techniques in Information Theory. The reliability of compressive sensing is that it capable to obtain a sufficiently exact estimation of an unknown data field. In this phase we are taking care of both accuracy and energy. Distinctively cross layer interaction by manipulate adaptive compressive sensing in WSN. Sparse sampling is a signal-processing system for obtain and reconstruct the signals in a dynamic manner, by computing way out to underdetermined linear systems. Which one belongs to that, with the help of optimization, the sparsity of a signal has been manipulated to recover it from the little bits of sample. From received sample, there is possible to directly recover the original signal by follows the non linear reconstruction method. In our WSN network, need to transmit the Ì bits of information to the BS in wavelet based compressive sensing manner. According to preprocessing step, information (Ì) is transformed into N number of samples. In Compressive sensing scheme, samples are taken as input by utilizing the orthogonal matrix, as a result of redundancy removal, we can obtain S amount of signals (N>>S). As per the Fig.2 when raw information becomes the S amount of signals, then proceed to the transmission step.

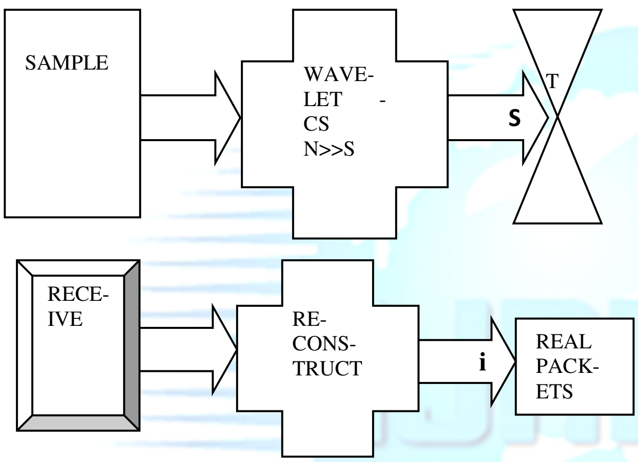

Fig.1 Compressed sensing Methodology

In our WSN network, need to transmit the Ì bits of information to the BS in wavelet based compressive sensing manner. According to preprocessing step, information (Ì) is transformed into N number of samples. In Compressive sensing scheme, samples are taken as input by utilizing the orthogonal matrix, as a result of redundancy removal, we can obtain S amount of signals (N>>S). As per the Fig.1 when raw information becomes the S amount of signals, then proceed to the transmission step.

We consider the major problem of recovering the signal Ì € R^N from data [10]. Let the orthogonal matrix Ø := [$\emptyset_1$, $\emptyset_2$, $\emptyset_3$,....,$\emptyset_N$] it act as a base class for R^n . We define that ' Ì ' can be expressed as a linear combination of S vectors from Ø. Then we can write

$\grave{I} = \sum_{x=1}^{S} \theta_{nx} \, \boldsymbol{\emptyset_{nx}}$ with $S << N^2$. ……(1)

Consider an M x N measurement matrix Ψ, M << N, where the rows of Ψ are jumbled with the columns of Ø matrix.

Now a day's broadly used sparse representation in signal and image processing is the wavelet transforms technique. Since piecewise polynomial signals have sparse wavelet expansions [18]. According to lossless data transfer, we focus on 1D signal, although similar arguments applied for higher dimensional data in the wavelet.

Each coefficient among the scale p Є {1, 2,.., P := $\log_2(N)$} it depicts the portion of the signal of size O

We prefer non-linear reconstruction to recover the Ì (information) directly from the sample and there is no need additional compression step is required.

3.2 Threshold based 2-tier Communication

N number of sensor nodes plotted randomly on the field area. Cluster formation is the optimal solution for energy efficient communication in WSN network. Every node has the probability to become a CH.

a) At every time slot we determine the threshold parameter.

b) Sensor node which one has the peak level of energy; then that node will act as a CH with respect to higher probability.

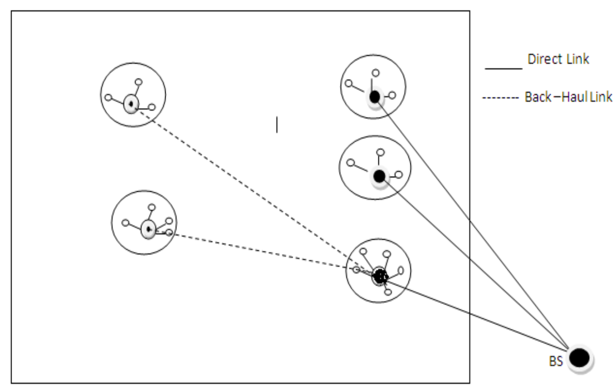

Fig.2 Hierarchy level Synch pattern

This is why our proposed framework jointly performs Compressive Sensing and Energy Efficient Clustering Routing. CH simultaneously collects the data from child node in event based manner. CH to BS communication link follows our hierarchical scheme (See Fig.2).

Assuming that the nodes are uniformly distributed, average distance between the CH and BS has formulated as eq. (2)

$dtoBS = 0.765\frac{M}{2}$ …….(2)

For each cluster head to base station routing path will be finalized according to the 2-tier firm.

$P_{opt} = \frac{k_{opt}}{N}$………(3)

Where $K_{opt}= N / d_{toBS}$ . . . .(4)

Eq (3) helps to determine the optimal number of clusters, to maintain the network stability.

At the time of CH collects the data, our framework calculates the distance between the CH and BS. In case the distance value accept the threshold parameter, then CH directly sends to the BS else share to the nearby CH.

1) Backhaul link:- CH – CH – BS
2) Access link:- CH-BS

4. Performance and Evolution

We performed the extensive simulation to assess the performance of HCSCAP protocol in matlab 2012 version. We found that the proposed protocol extends the entire network life time by 2-tier communication. And also save the bulk of energy by the utilization of wavelet based compressive sensing.

The simulation of HCSCAP network structure, defined as 100 sensor nodes were randomly deployed across the field area of 100 v 100 m^2 (depicted in Fig.3). The transmission range of each sensor was set to 60m. We consider the 2-tier regime based on the threshold parameter of the CH.

Here we follow 2 kind of sensing modes, (CS) Compressive sensing and (NCS) Non-Compressive sensing. In our work Cluster Head (CH) has special permission to communicate over "CH" / "BS" in CS mode. Because large amount of data transferring from CH to Sink.

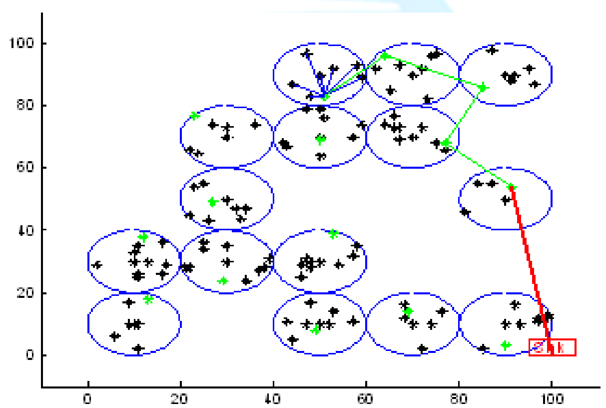

Fig.3 Cluster formation

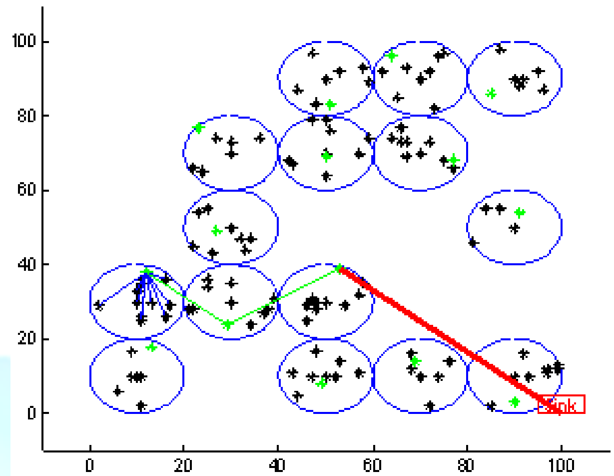

Fig.4 Backhaul link based synch pattern

Whenever the Cluster head's threshold parameter is acceptable, then it communicates to the BS w.r.t access link pattern. In case threshold is not acceptable, then it communicates to the BS w.r.t Backhaul link pattern. Figure 4 and 5 demonstrates the Backhaul link and access link respectively. Figure 5 also shows if distance between cluster head and sink is less than 120 meter then cluster head directly transmits signal to the sink instead of sending nearest cluster head in upstream direction.

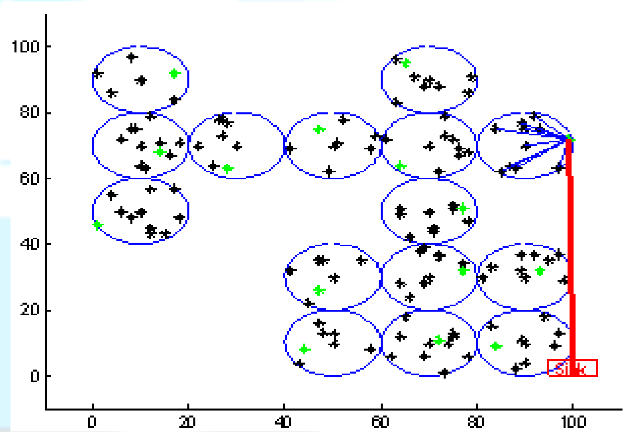

Fig.5 Access link based synch pattern

Figure 6 shows data transmission to the sink by cluster heads. In this cluster heads collects packets from lower cluster head, compresses data and transmits to upper cluster head.

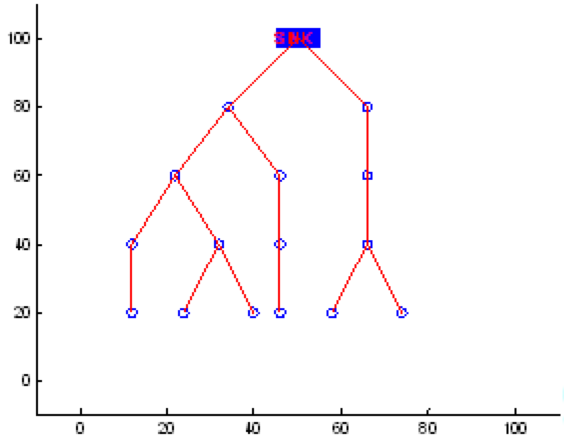

Fig.6 Network model: CH to BS Communication (Circle depicted as CH)

Figure 7 illustrates the congestion aware routing performance over the entire simulation time. it shows queue length, it varied according to number of packets and packet size.

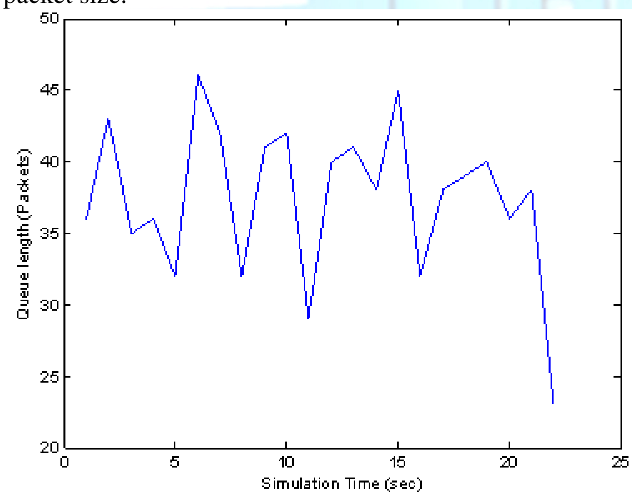

Fig.7 Process time Vs Packet queue length

Figure 8 illustrates the Data rate Vs packet count sizes

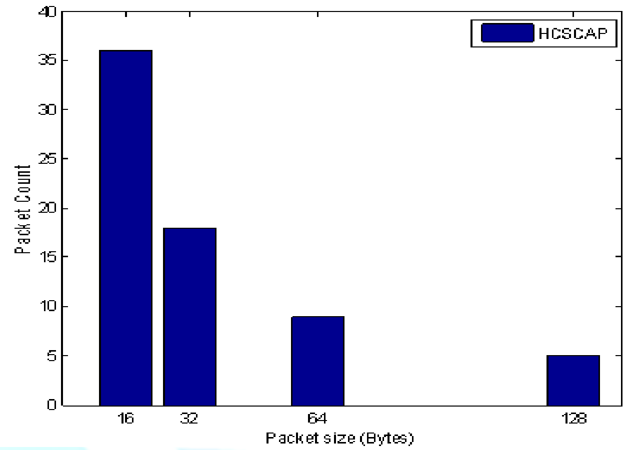

Fig.8 Data rate Vs packet count

Figure 9 illustrates the Data rate Vs Time delay

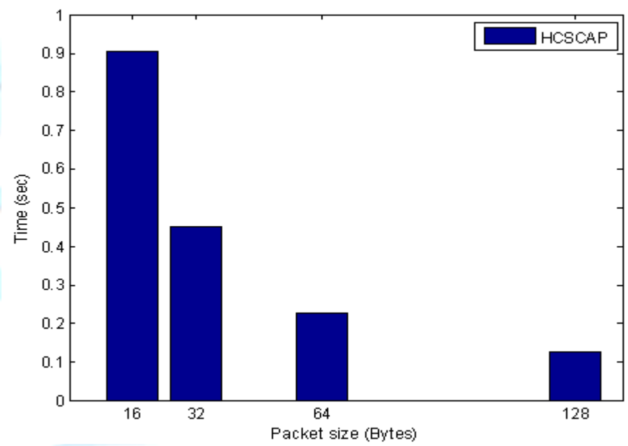

Fig.9 Data rate Vs time delay

In figure 10, 11, 12 and 13 we compared (Prioritized heterogeneous traffic-oriented congestion control protocol) PHTCCP with HCSCAP protocol.

Figure 10 demonstrates the impact of packet service ratio over weighted average queue length. It shows that weighted average queue length is directionally proportional to packet service ratio. As the result of buffer overflow congestion leads at the time of routing.

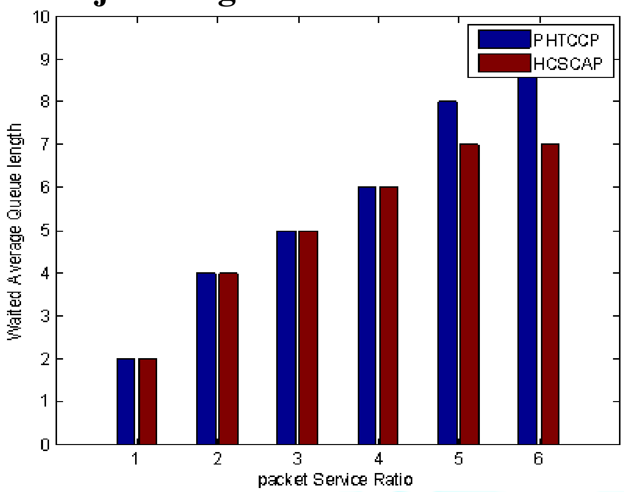

Fig.10 Congestion parameter Vs Average queue length

Figure 11 shows the maximum memory requirements for different sizes of a packet (Ex: packet sizes 16,32,64,128 Bytes). Memory requirements have been calculated by the following formula.

$M_{req} = N_q \times P_l \times q_s$ . . . . . .(6)

N_q → Number of queues

P_l → Packet Length

q_s → Size of each queue.

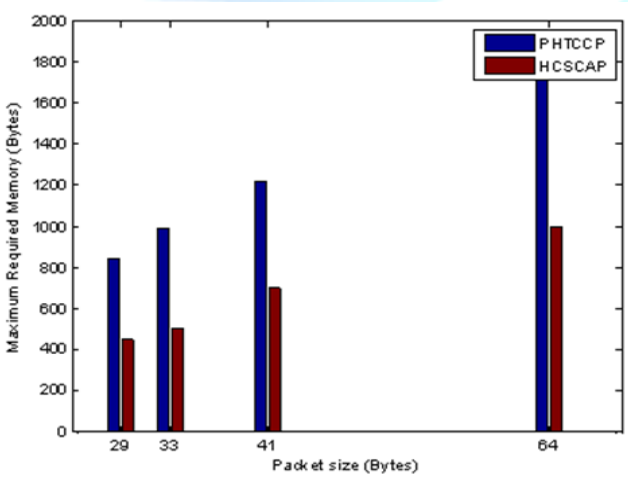

Fig.11 Required Memory Analysis

Figure 12 compares the energy efficiency of proposed methodology (CSCCP –Compressive sensing congestion control protocol) over PHTCCP.

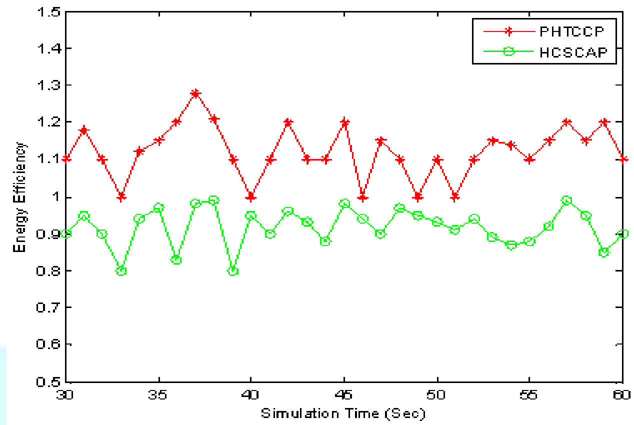

Fig.12 Energy consumption during the total simulation time

Figure 13. Compares the normalized system throughput between the CSCCP and PHTCCP. CSCCP system bandwidth is most of the time normalized to 1 during the overall simulation process. Which means CSCCP methodology achieves higher system throughput.

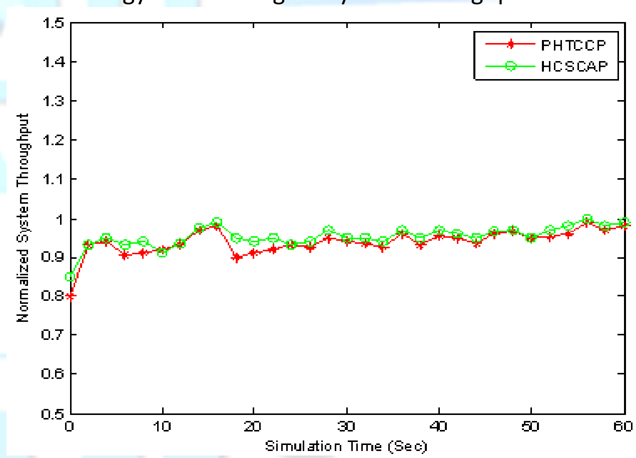

Fig.13 Network throughput ratio (This fig illustrate proposed technique reduce the number of packets in flight)

5. Conclusion and Future work

This paper has developed a framework for wireless sensor network to perform congestion aware data processing. Packet loss, delay and excess of energy consumption; the above phenomenon are fundamental reasons to lead congestion at the time of data aggregation. With this proposed technique we break the all kinds of existing obstacles by utilize wavelet based compressive sensing in Hierarchical manner. According to HCSCAP protocol, needs some improvement on security premises. This is why we direct our future work, secure encrypted data processing as well as maintain the energy budget.

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