H-SIR:Heterogeneous Source Initiated Reactive Protocol for Wireless Sensor Network

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ABSTRACT
The impact of energy based heterogeneity is investigated through Source Initiated Reactive algorithmfor event driven applications to understandthe impact of heterogeneous network on energy efficiency and network lifetime. Based on the simulated experimental and numerical results, it is found that the energy efficiency performance is enhanced by 24% for correlated and 40% for uncorrelated event detection by interposing heterogeneity. Withthe aid of these observations,one can say that this novel approach can help us contribute in the energy-efficiency context, and future solutions can take advantage of the proposed algorithms and observations.

General Terms
Wireless Sensor Network (WSN), Heterogeneity, Source Initiated Reactive(SIR) Algorithm.

Keywords
Event Detection; Heterogeneity; Spatial Correlation; Temporal Correlation; Routing; Energy-Efficiency.

1. INTRODUCTION
Advances in the Sensor technology in the past few years have transfigured the way we live and work. With the rapid technological developments of sensors, Wireless Sensor Network (WSN) has become the key technology in information gathering and communication systems, featuring easier deployment and improved flexibility along with enhancing the reliability and efficiency of infrastructure systems. A WSN is a network of a vast number of spatially distributed autonomous sensor devices, called motes, where each mote senses, processes and communicates the sensed phenomenon to the Base Station (BS) through wireless links. The deployed motes direct the sensed information wirelessly to the neighboring motes as well as to the BS, necessitating the use of an efficient routing algorithm for creating the paths between the motes.

In WSNs, a number of routing algorithms are already in place [1].Classical approaches presume that all the network motes are homogenous regarding battery life. However, the effect of just employing heterogeneity in the network may prove to bring forth a substantial effect on a network regarding energy-efficiency [2]. The impact of heterogeneity would benefit considerably to a vast number of applications. One of these applications could be energy replenishment of sensor motes. When a considerable number of motes die, more motes can be added to the network having battery life more than the motes alive in the network, which causes energy heterogeneity. There are numerous applications [3] where the total number of sensor motes is restricted. It will be justified to observe the effect of adding more energy to the existing motes on the network lifetime. Motes further away from the BS consume lesser energy than the motes present near the BS, thereby, tending to stay longer and creating unequal energy consumption in the network. Hence, heterogeneity paves its way to a large number of real-life applications. Keeping this in view, in this research work, a source initiated routing (SIR) approach is implemented and evaluated on heterogeneous networks [4].

Further, three different variants of heterogeneity namely: two-level, three-level and multi-level are evaluated, allowing for the dissimilar energy levels of the motes in the network. In, two-level simulations, there are two different kinds of motes deployed in the network, having different energy levels. The motes with higher energy level are categorized as advanced motes and the motes with lower energy level as normal motes. Similarly, three-level heterogeneity classifies motes as super motes, advanced motes, and normal motes in the order of increasing energy levels. Multi-level heterogeneity considers the random energy levels of motes in the network.

In addition, SIR approach is used for event detection applications which can be classified as correlated and uncorrelated event detection. The temporal correlation of the events occurring in the network differentiates the two types of event detection. Correlated detection submits that the events occurring at a single point of time are interrelated and hence, can be evaluated together. Hence, Gaussian distribution can be considered for correlated event detection. On the contrary, uncorrelated detection considers no interconnection among the events occurring in the network, thereby making the Uniform distribution suitable for defining the uncorrelated event detection.

2. PROBLEM STATEMENT
To systematize a generic model for heterogeneity, system can be modelled as a sensing area of interest A where n number of motes are randomly deployed. The motes are deployed uniformly with a homogeneous mote density of: $\rho = n / A$. Three variants of heterogeneous network are modeled: two-level, three-level, and multi-level. The scope of the work is to simulate SIR on the homogeneous as well as the heterogeneous network. For the simulation purpose, motes with different levels of battery life are deployed to achieve heterogeneity. The stimulus behind heterogeneity based on energy levels is that more energy levels can be given to some motes such as the sink or the motes nearer to sink, which consume more battery life, so that the network achieves uniform drainage of energy. Hence, the scope of the work is to study different levels of heterogeneity vis-à-vis its homogenous counterpart. Simulations have been done to observe total energy consumed in Uniform distribution for uncorrelated and Gaussian distribution for correlated event driven applications.

3. RELATED WORK

A large number of routing algorithms suitable for different kinds of applications are already in place [5]. A commonly used approach for routing the data to the sink is a reactive one. The route is discovered only when there is a mote which needs to transmit the data to the sink. This is an approach for a low frequency event occurrence as it will save the overhead time for maintaining the routing table. One example of this approach is the Source Initiated Reactive (SIR) [6].The study taken as literature cite explained the SIR approach and its advantages over traditional algorithms. An enhancement is proposed in the routing strategy by using gossiping instead of flooding approach [7].

Further in this research work, the impact of heterogeneity is studied to enhance network lifetime for the current levels claimed. For achieving this goal, an algorithm called H-SIR (Heterogeneous Source Initiated Reactive) has been designed and implemented. The related work close to the heterogeneous deployment and its impact is presented in this section. As per claims of the paper [8], the heterogeneous network is superior to its counterpart homogeneous network in terms of improved coverage and lower cost. The suitability of heterogeneous WSN for real-life applications is studied and surveyed by Mhatre et al. [9]. Similarly, Vivek et al. suggested energy based heterogeneity to elongate network lifetime and to enhance reliability and response time [10]. However, reactive protocols were used in the detection of events and the motes create paths instantly. Push Diffusion [11] showed through field experiments that the selection of a particular heterogeneity level affected the network lifetime by 40-60%. In addition, the temporal characteristics of event driven applications must be kept in mind while doing the analysis of a particular routing algorithm. The different kind of event detection can be simulated using Gaussian and Uniform distributions, leading to different temporal characteristics of the application [12].

4. WORKING DESCRIPTION OF PROPOSED APPROACH

The proposed approach creates the path as soon as the event is detected. Only the mote that detects the event is required to create a path to the base station. This approach increases the reactive behavior of the routing strategy and hence is more efficient in intense traffic environments. The sensing mote that detects the events selects the parent neighboring motes to broadcast the data. Parent mote is selected based on four different parameters, namely, the distance to the base station, residual energy, a selection factor which is determined from a probability that a mote has not yet been elected as a root mote in the previous *m* rounds, and the number of neighboring motes. The mathematical formulation for selecting the parent mote is:

$$S(l) = \min_{s,i\in n}(s,i)(s,i) + \frac{E_{residual}}{E_{total}} + SF + count(n) \quad (1)$$

Where, *SF* is the selection parameter based on the probability that a mote has not been elected in the previous *m* rounds, and is computed as:

$$SF = {}^{m}\Big/ (1 - m(r\left(mod\left(\frac{1}{m}\right)\right)) \quad (2)$$

Where, *m* is the factor to ensure that the previously chosen parent mote is not selected in the current round *m*. In other words, *m* is the number of parent motes that are to be elected.The working of SIR protocol is given below:

1. The sensing motes detect an event, process the data and broadcast a control packet containing its *source_id* and the timestamp to *n* random number of neighboring motes.
2. Receiving motes store the *source_id* and the timestamp of the sender mote. These motes further send the control packets to *n* number of random neighbors.The motes will keep on forwarding the control packet until the BS is reached.
3. After the BS receives the control packet from the neighboring motes, it sends a data initiation message to the sensing mote.
4. Control message sent by the BS backtracks to the sensing mote and hence, a routing path is created.
5. As soon as the sensing mote receives the control message, it updates its routing information, following which the data transfer can take place on the generated path.
6. The topological changes that might occur due to failure of connection links or the motes are handled by BS, which keeps on sending the requisition messages to the network.
7. The routing of data packets continues till the time the event is happening and the sensing mote is sending the data packets. As soon as the sensing mote stops sending the data packets, the BS will stop sending the requisition messages and the routing paths are disjointed.

5. SIMULATION AND PERFORMANCE EVALUATION

The experiments are conducted to evaluate the energy analysis considering both homogeneous and different variants of heterogeneous network, i.e. two-level, three-level and multi-level. Here the performance evaluation on two different aspects of event driven applications are considered. First, the effect of uncorrelated simulation of events using uniform distribution is evaluated. Subsequently, the correlated events simulated using Gaussian distribution is simulated and evaluated. The results based on the above simulation setup for various parameters are demonstrated below. The energy model used here in H-SIR undertakes the total energy consumption of a single round of simulation as the sum of energy consumed in the exchange of data packets and control packets. The sensor network is simulated as an area of $50x50m^2$ for 100 number of motes. Energy spent in transmitting and receiving the data packets is 50 nJ/bit the packet size is 4000 bits. The initial energy of the normal mote is 0.5J.

5.1 Performance Metrics and Evaluation

This section evaluates the result of proposed H-SIR for the heterogeneous network. The performance metrics used is the Total Energy Consumed and the comparisons are drawn between the homogeneous deployments with the different variants of heterogeneity [13]. Heterogeneity parameters are provided in Table 1.

Table 1. Heterogeneity Parameters

Network	Advanced Motes		Super Motes	
	Fraction	Additional Energy	Fraction	Additional Energy
Two-Level	0.3	1.5 times	0	0
Three-Level	0.3	1.5 times	0.2	3 times
Multi-Level	Closed set[0.5,2]		Closed set[0.5,5]	

5.1.1 Energy Analysis for Correlated Stimuli

The results depict that the amount of energy spent is lowest in multilevel heterogeneous WSN. Homogeneous WSN consumed the most energy. This is attributed to the fact that super motes have 300%, and advanced motes have 150% more energy than the normal motes. Henceforth, two-level exhibits 24%, 3-level exhibits 48% and multi-level touches 64% better performance.

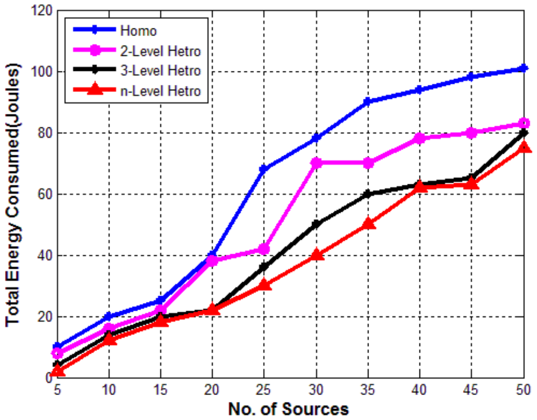

Fig 1: Energy Analysis for Correlated Stimuli

5.1.2 Energy Analysis for Uncorrelated Stimuli

For Uncorrelated event detection, a uniform distribution of events is assumed. Hence, an average parameter is calculated. The energy bracket for heterogeneity reduces to [4-75] Joules as compared to [10-120] Joules. Fig. 2 shows that two-level and three-level behave in a similar manner and displays a modest performance over the homogeneous network. Multi-level shows a wider comparison through an average of 85%. The reason is that the events are assumed to be unrelated and hence the drainage of energy cannot be predicted.

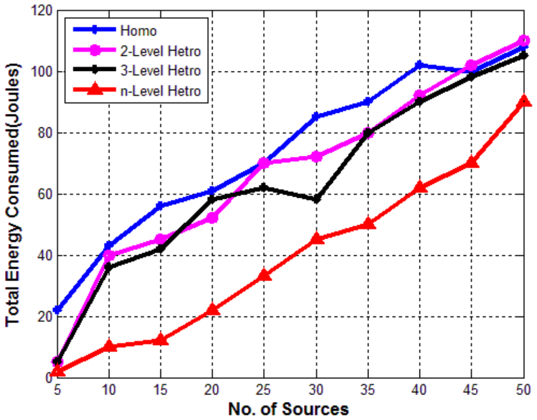

Fig 2: Energy Analysis for UncorrelatedStimuli

6. CONCLUSION

This manuscript discusses the utility of heterogeneity based source initiated routing apparatus. The series of experiments show that heterogeneity is better for energy efficiency and for maintaining the network operations. The results also confirm that higher degree of heterogeneity produces better results. The best outcomes have been observed with the multi-level (H-SIR) based network experiments. It was found that multi-level Heterogeneous network has a higher energy efficiency and the motes die at a slower rate in comparison to SIR and all other variants of H-SIR. The residual energy is also more as compared to the two-level heterogeneous network (H-SIR). The better results are attributed to the dynamic nature of H-SIR algorithm, owing to which it was able to handle traffic in a more sensitive manner.Future scope of the proposed work lies in exploring spatial correlation of the events as it has direct impact on the event driven applications.

7. REFERENCES

[1] B.D. Shivahare, C. Wahi, S.Shivhare, "Comparison Of Proactive And Reactive Routing Protocols In Mobile Adhoc Network Using Routing Protocol Property", International Journal of Emerging Technology and Advanced Engineering, vol.2,pp.356-359,Mar,2012.

[2] Chae, D., Han, K., Lim, K., Ahn, S., "An, S.-S. A Localized Route Discovery for On- Demand Routing Protocols in Event-Driven Wireless Sensor Networks." IEICE Trans. Commun. 2006.

[3] Lei Mo,Bugong Xu, Xiaoping You, Longqing Liu, "Distributed Lighting System Based on Wireless Sensor and Actuator Networks," Ad-hoc Wireless Sensor Networks, vol. 20, Issue 1-2, pp. 273-295, 2013.

[4] Carlos M. S. Figueiredo, Eduardo F. Nakamura and Antonio A. F. Loureiro, "A Hybrid Adaptive Routing Algorithm for Event-Driven Wireless Sensor Networks," Open Access Sensors, vol.9, pp.7287-7307, Sep, 2009.

[5] Heinzelman, W.R.,Chandrakasan. A.,Balakrishnan. H., "Energy Efficient Communication Protocol for Wireless Micro Sensor Networks," Proceedings of 33rd Hawaii International Conference on System Sciences, Jan 2000.

[6] Sharma, Nonita, and Ajay K. Sharma. "Cost analysis of hybrid adaptive routing protocol for heterogeneous wireless sensor network." Sādhanā 41.3 , pp.283-288, 2016.

[7] Sharma, Nonita, and Ajay K. Sharma. "Comparative analysis of SIR and SID in Wireless Sensor Networks using temporal correlation." In Computing, Communication & Automation (ICCCA), 2015 International Conference on, pp. 464-468. IEEE, 2015.

[8] H.Kour, A.K.Sharma, "Hybrid Energy Efficient Distributed Protocol for Heterogeneous Wireless Sensor Network," International Journal of Computer Applications (0975 – 8887), vol.4, pp.1-6, Jul 2010.

[9] Li Qing, Qingxin Zhu, Mingwen Wang, "Design of a distributed energy-efficient clustering algorithm for heterogeneous wireless sensor networks," Computer Communications, vol.29, pp.2230-2237, Aug 2006.

[10] Mhatre, Vivek, and Catherine Rosenberg, "Homogeneous vs. heterogeneous clustered sensor networks: a comparative study," Communications, 2004 IEEE International Conference, vol. 6. IEEE, 2004.

[11] Vivek Katiyar, Narotam Chand, Surender Soni, "Clustering Algorithms for Heterogeneous Wireless Sensor Network," International Journal of applied engineering research, Dindigul, vol.1, pp.273-286, 2010.

[12] Nakamura, Eduardo F., Antonio AF Loureiro, and Alejandro C. Frery. "Information fusion for wireless sensor networks: Methods, models, and classifications." ACM Computing Surveys (CSUR), pp. 9, 2007.

[13] Sharma, Nonita, Ajay K. Sharma, and Kumar Shashvat. "Impact of Heterogeneous Deployment on Source Initiated Reactive Approach." International Journal of Advanced Computer Science & Applications 1, no. 6: 185-191.