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ORNEV: Optimized Recharging of Wireless Sensor Networks using Virtual Base Stations

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Abstract**—** Several recharging methodologies and frameworks have been proposed for recharging wireless sensor networks. In this paper we study these propositions and device a method that would enhance the recharging capability of the framework and keep the network up and running without the energy getting depleted. We explore a new dimension where we use the SenCars used for charging a node to transmit data just like a node in the WSN. The SenCar acts like a virtual base station for a node that carries high traffic that it will be charging. This cuts down transmission of data through nodes that connects the high traffic node with the base station thereby moving them to sleep mode. This SenCar then directly transmits traffic information from the node it is charging to the base station using cellular technology.

Keywords*-component; Wireless Sensor Networks, WSN, optimized recharge, virtual base station, sencar, sencar charger*

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I. Introduction

A new dimension has opened to power wireless Sensor Networks with the advancements in Wireless Energy Transmission (WET). With contrast to old energy utilization techniques WET method has opened doors to new ways, where nodes can be reliably energized without the clutter of wires and plugs.

Now, recharging wireless networks are facing a bottle neck of unavailability of a continuous energy source that could replenish the devices when they run out of juice. Several other constraints like performance during the recharging and transmission of information across the network could also reduce the efficiency of energy transmission. Besides these physical issues that cannot be rectified beyond a certain limit, there are those which require improvements at a logical level like the strategies and algorithms used for communication.

In this project we study the existing frameworks used for recharging Wireless Sensor Networks (WSNs) [1] and device a method that would enhance the recharging capability of the framework and keep the network up and running without the energy getting depleted. We explore a new dimension where we use the SenCars used for charging a node to transmit data just like a node in the WSN.

The SenCar acts like a virtual base station for a node that carries high traffic that it will be charging. This cuts down transmission of data through nodes that connects the high traffic node with the base station thereby moving them to sleep mode. This SenCar then directly transmits traffic information from the node it is charging to the base station using cellular technology.

II. Literature Survey

LEACH is one of the first protocols implemented in hierarchical routing which proposed the fusion of data [2] [21]. Here, the nodes in the network organize themselves into local clusters with one of the node acting as the cluster head. LEACH utilizes the randomized rotation of cluster heads to evenly distribute the energy load among the sensors in the network.

TL LEACH is one of the variants of LEACH protocol that was discussed in the above section.

The enhancement made in this protocol is that cluster formation process is realized as a two-level hierarchy where ever possible in the network. The advantage here is that the distance covered by transmitted data between the base station and the bottom nodes is reduced as compared to LEACH [1]. VLEACH is another variant of LEACH protocol [4].

HEED is a clustering method which considers the residual energy in the nodes for forming clusters [5]. Here the node with the highest energy is elected as cluster head node. Cases where the highest residual energy is same, the cost for communication between the nodes is considered to select the cluster head.

EECS is typically similar to the LEACH clustering scheme where the network is partitioned into a set of clusters where each cluster contains one cluster head [6]. Interaction between the cluster head and BS happens in a single hop. However unlike LEACH, cluster formation in EECS is executed by dynamic sizing of clusters based on cluster distance from the base station. Thus the problem of energy efficiency in cases where the BS is far from the cluster head is resolved here.

BSCDCP has 2 major phases in its procedure Setting up and Data Communication [7]. As the name suggests, during the cluster formation process, the BS selects the right candidates from the nodes to be the cluster head. An algorithm is used to split the network into clusters continuously. Messages are aggregated at the cluster heads and sent across to the BS in multiple hops.

TEEN protocol design facilitates nodes to react immediately towards sudden changes occurring in the value of a sensed attribute beyond a pre-determined threshold value. It is well suited for time critical applications [8]. The process which excludes the threshold value is equal to LEACH [2]. The method used for cluster formation is also same as LEACH.

APTEEN is a hybrid protocol for efficient routing that adapts the advantages in both LEACH and TEEN. It utilizes comprehensive information retrieval [9]. Data transmission in APTEEN follows the threshold value of TEEN and the periodic data transmission is done as in LEACH. Such a network enables the user to request past, present and future data from the network in the form of historical, one-time and persistent queries respectively.

“ARCS” is a protocol based on a dynamic cluster and proactive network which has been proposed for environmental monitoring [10]. All nodes in the network are assumed to transmit data in a multi hop fashion. Unlike other schemes discussed so far ARCS uses more parameters other than the energy levels for developing the clusters. It makes use of the altitude and sensed value parameters passed on by the node.

ARCS-T is a protocol based on dynamic clustering. Its working is solely based on the transmission of data from the clusters or network during static intervals of time.

PEGASIS is a data aggregating and highly optimized chain based algorithm that suggests the theory that the conservation of energy can result from nodes not directly forming clusters in the network.

CCS protocol was proposed in [14] to minimize the power consumption by nodes in the PEGASIS protocol discussed earlier. Here, the whole wireless sensor network is divided into concentric circular paths with each one of these paths representing a cluster and each is designated with a level.

NETWRAP happens to be a recent proposition on improving the routing efficiency of a WSN [11]. It makes use of Named Data Networking (NDN) proposed for the internet [12]. Here the data being communicated are referred to with their names rather than using the recipient's address.

III. PROPOSED FRAMEWORK

The recharging of sensors is done using SenCars on receiving the updated energy level statistics from sensors in real time. First, the network is divided into different areas depending on their density and each area is given a unique name. A head node is selected in each area which will be responsible for aggregating and communicating the energy information of the nodes belonging to the same area. For increased robustness, the node in the area with highest energy level is selected as the head node. This is done at network start up as discussed in later sections.

Energy information collection is triggered by the SenCar by sending out energy interest message to the head nodes in the topmost level of the hierarchy. The head nodes then send low energy interest messages to the child heads in the lower level areas. This process is continued along a path down the head node hierarchy until the message reaches the leaf nodes of the hierarchy. Once this message is received, the response is sent from the lowest level nodes in the reverse direction of the path. The response to the local head node includes the ID of the node ad its energy level.

The local head node, on receiving this info propagates it to higher nodes if the energy level mentioned is lower that a threshold normal value that is set by the network administrator. As this process continues we can see that by the time the top level head node receives the reply, it would be having a list of all nodes and regions where the battery level is low and needs recharging.

Figure 1 shows a sample network where the communication between the head nodes happens across intermediate nodes to transmit energy information. Here Nodes A, B and a head node belong to the same area and hence grouped into an oval.

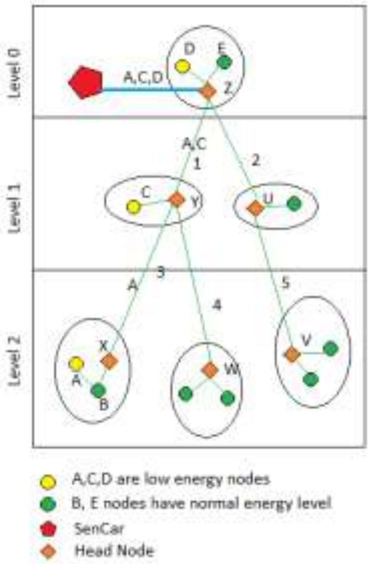

Figure 1: Energy Interest propagation across the head node hierarchy

Now, the interest message from the SenCar queries the top level head node Z ad lower interest messages are transmitted down the hierarchy to head nodes and U and from there to the next level X,W and V. Suppose we only have A,C and D which have below normal energy levels. So the responses start from lowest level where A,B send their energy level to X, X filters out B as it has above normal energy and passes on Energy level and ID of node A to the higher node Y.

Also note that along with the Node and their energy level, the area (the oval shape containing the nodes in Figure 3.3.1) to which the belong is sent to the next head node Y passes on Node A and Node C info to Z and finally Z collates all the low energy level nodes and sends it to the SenCar which forms the list to recharge the nodes.

Also, it is worth noting that it is not necessary that the information is directly transmitted to a higher level head node from the head node in a sub region directly as shown in Figure 1. If there are no higher level head nodes in the vicinity, the information is propagated to a higher level head node via one or more intermediate nodes.

Consider the network provided in Figure 2. It is divided into 3 regions - “a/a”, “a/b” and “b” using NDN. Once the connections are established between the nodes and finally to the base station, the network is all ready to start detecting activities and reporting them to the base station.

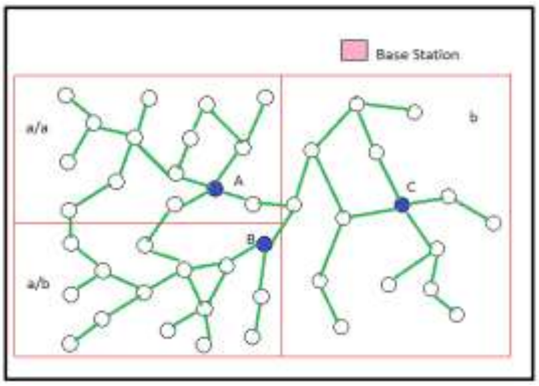

Figure 2: A WSN divided into areas based on NDN

IV. Normal Recharging Scenario

Once the network is set, SenCars are sent towards the Head Node of the Areas having high activity that is farthest from the BS in the WSN based on some initial traffic analysis as shown in Figure 3.

However it is not assigned to charge this node currently. This gesture is initiated by the BS as an effort to predict the nodes that would raise the first interest for recharging and thereby sending a SenCar to the location beforehand. This initial move helps position SenCars at locations where maximum chances exist for a recharging activity and hence reduces the latency involved by the time consumed for the SenCar to move to the node after it raised an interest for recharging.

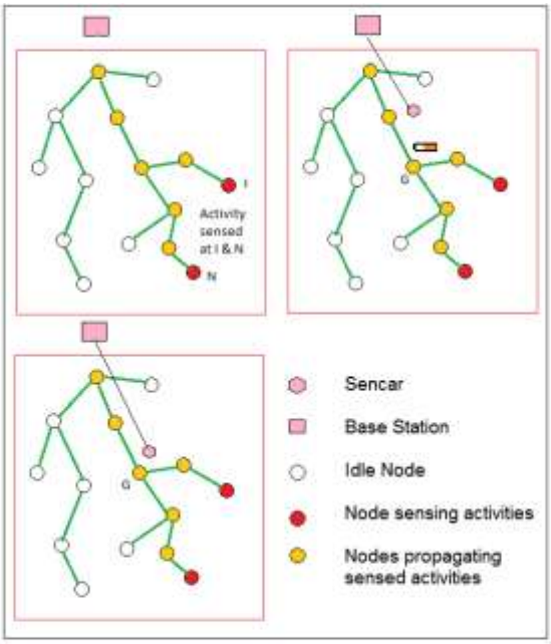

Figure 3: SenCar traversal from BS to the node needing charging

SenCars send energy interest Requests (EIR) to the nearest head nodes in those areas along which it travels. These head nodes send lower level energy interests to the child level heads coming under their corresponding sub areas. This process continues till the information reaches all the nodes in the lowest sub areas. As a response to this message, the nodes send a reply energy interest response (REIR) containing their ID and their current energy levels. The REIR is sent only if the energy value is below a normal threshold. The lower level heads receive the REIR and sends it to its parent node in the increasing order of the energy level received, to reduce the transmission overhead. Thus, the head nodes of each area get the current energy levels of each node in that area that needs to be recharged.

The head nodes on the top most levels will be aware of lower level regions having low energy and the lowest level head node will be aware of the exact nodes that require to be recharged. This info is important because it could be used to recharge the nodes in a low energy region and hence reduces the distance that the SenCars needs to travel. It would be worth noting that the aggregation of energy information happens at the head node only when the SenCar queries for it.

If there are multiple SenCars that query the same head node, the SenCar that is nearest to it processes the request. This helps reduce the travel cost incurred by the SenCars.

The SenCar retrieves the list of nodes to be recharged from the head node. On reaching the proximity of the first node in the list that needs to be charged, it projects itself as a base station and sends a Virtual Base Connect Request Signal (VCR) to the node and waits for connections from neighboring nodes. The node verifies the authenticity of the SenCar by comparing the encrypted MAC ID it received from the Base Station via the network with the MAC ID provided by the SenCar. The encryption can be done using DES as discussed in [20]. If it matches, the node floods a Node Notification Signal (NN) containing the encrypted MAC ID of the Virtual Base Station to its neighboring nodes (N_x where x can be any whole number). When the nodes which are neighbors, receive the NN signal they check if a Virtual Base Station is in their vicinity. If so they establish direct connection with it by sending a Node Connection Request (NCR). If it connects successfully, the Virtual Base Station replies with a Node Connection Success Response (NCS). This node then disconnects from the recharging node after sending a Node Disconnect Notification (NDN).

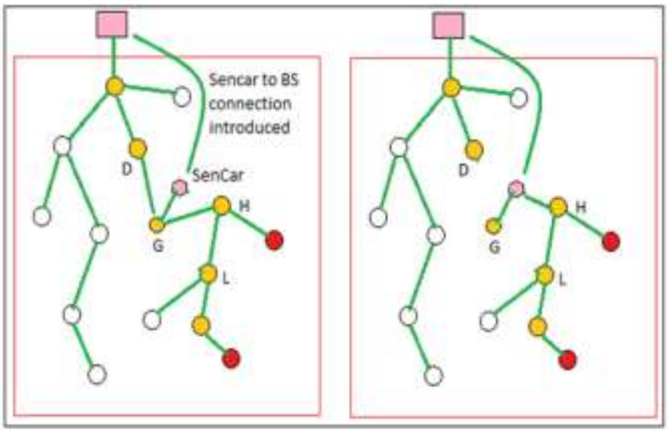

Figure 4: (a) SenCar Establihes conection with the node needing recharge as a virtual base station. (b) H disconnects from G and conects to the virtual base station to form a disconnected graph

The VBN signal being flooded causes each node in the network to update its distance from the Virtual Base Station. The flow of data within the network is modified such that the other nodes in the network either choose to send their data to the BS or to the Virtual Base Station, whichever lies in the shortest path. So as illustrated in Figure 4(b), Data flow from D to G is stopped as D is nearer to the BS and G is connected to the virtual base station. The SenCar is equipped with long distance communication antennas (Cellular or Wi-Fi), so it directly propagates the data it receives to the BS thereby reducing the traffic caused by sensed data and EI data within the network.

Once the node is charged completely, the SenCar sends a Virtual Base Disconnect Notification Signal (VDN) and goes offline at a point where there is no traffic in the line it is connected to. The VDN refreshes routing tables of Nodes by setting the entry to the Virtual Base as a large value indicating disconnection and hence returns to the old graph structure of the network.

The timing diagram given below shows the signals being exchanged between the virtual base station and the nodes.

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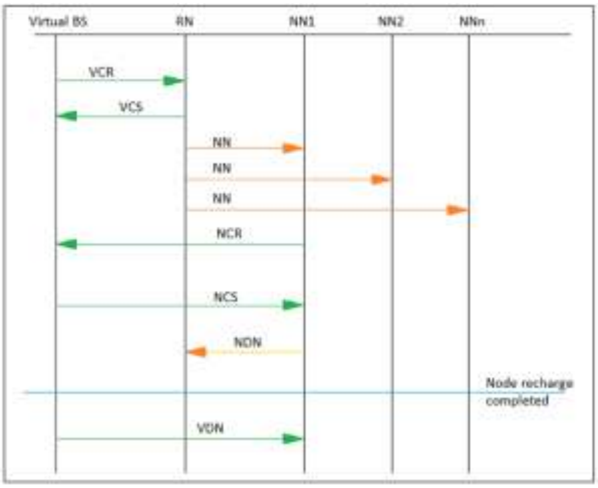

Figure 5: Timing diagram showing the important signals interchanged by the virtual BS and Nodes

V. Emergency Recharging Scenario

For emergency conditions that involve situations where the battery level of nodes goes below a dangerously low threshold level, the node initiates sending the Emergency Interest request (EIR) to propagate it to a proxy node that manages the area. Once a SenCar finishes recharging a node and disconnects from the network, it sends an emergency Query request (EQR) to check if an emergency has occurred. The proxies respond with the Node IDs that raised the EIR, their residual life time and energy levels. On getting this info, the SenCar uses the Emergency recharge algorithm to determine which one to recharge first.

VI. Routing Table modifications in the Nodes

The routing tables stored in each node in the network are updated using OSPF algorithm [20]. A new enhancement here is that the routing table will be having an entry for each SenCar (Virtual Base Station) that can be released into the network to re-energize it. A large value is initially assigned to it to indicate that it can't be located. When a SenCar re-energizes a node, this value is updated across the nodes through the NN signal flooded by the node that is being charged by the SenCar.

VII. SenCar goes Offline after re-energizing

Once the SenCar charges a node, it needs to detach itself from the node so that it can move on to the next node in the network for recharging. However, this sudden detach can cause loss of data and also a broken network which could require a re-initialization. Hence the Virtual Data Base sends a signal (VDN) to all connected Nodes. Nodes getting the VDN refresh their distance from the Virtual base station with a higher count. The node connections rearrange to form a connected graph as it was before the Virtual base station attached to the WSN.

VIII. High Traffic and High Activity Areas

When the Network is initialized, its traffic due to activity sensed by the nodes in the WSN is analyzed by the BS. The nodes having high activity are recorded and a set of nodes where high traffic is being sensed is selected from a sample data. The SenCars are sent to these locations even before an emergency occurs.

The advantage of doing this is twofold. Firstly, we are able to predict the locations that would require a recharging soon so that we can be prepared for it. Secondly, the response time of the

SenCar to charge the next node is reduced to plausible level and hence we are able to respond to a node that requires servicing at a faster level.

IX. SenCar Preliminary Path Prediction

The initial SenCar path prediction algorithm is implemented as follows:

1. The BS selects the nodes that are having the highest traffic after analyzing the data received from the network.
2. It then analyzes the type of activity associated with the information in each node and categorizes them based on location. This step gives us a set of nodes that can be categorized on the basis of traffic associated with each activity.
3. The BS selects several activity categories (equal to the number of SenCars), causing the highest traffic and sends out the SenCars to the nodes causing this high activity.

X. SenCar Battery Replacement Algorithm

Unlike the algorithm required for recharging the sensor nodes, the SenCar Battery Replacement Algorithm is quite simple as there are only a few SenCars involved in a WSN.

The following assumptions are made:

1. The SenCar Charger approaches the SenCar for charging only while the latter is connected to the WSN as a virtual base station.
2. SenCar Charger follows the same route taken by a SenCar from the BS to the node it is charging it would be safe to assume that the SenCar Charger takes the same path the SenCar took from the BS to the node being charged
3. SenCar Charger makes pit stops at the base station once all the batteries in its possession are replace with empty ones from the SenCar.

The SenCar charger has n_s/N_C number of batteries when it moves into the field where ns and NC are the available SenCars and SenCar Chargers counts respectively.

The Algorithm:

1. SenCar checks its battery level just before establishing itself as a Virtual Base Station and notifies the BS if it has reached a medium threshold level and continues its work as a Virtual Base Station.
2. While the SenCar stays connected to the WSN, the SenCar charger traverses towards the SenCar and waits nearby if the SenCar is still connected to the network.
3. Once the SenCar disconnects from the network the battery is replaced by the SenCar Charger.

XI. Charging a SenCar

Since SenCars also have the added responsibility of transferring the traffic it receives in the WSN to the base Station directly, WSNs will require to replenish their batteries earlier than the scenario where they are used just for charging. This can be addressed by introducing SenCar Chargers. These are mobile vehicles connected to the Base Station via GPS. They are used to transport batteries from the base station to the SenCars in the field.

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As and when the SenCar reaches a threshold minimum energy, it sends a request to the Base Station requesting recharge the same way like a sensor ode sends an emergency message to the nearest SenCar.

The advantage of using a SenCar Charger instead of sending the SenCar back to the base station is that the SenCar can stay in the vicinity of the next node to be recharged hence reduces the response time for recharging the next node. The task performed by a SenCar charger is simple. It reaches the SenCar to be recharged and replaces its battery.

We can use a simple Bernoulli process to design a node's energy utilization: with probability p it consumes unit energy in a unit time slot [17]. The assumption is quite straight forward for most of the applications of sensor networks. For instance, in an event-driven sensor network, events occur at irregular intervals and are associated with a Poisson distribution. Once the unit time slot becomes small enough, such that only one event occurs in that time slot, the Poisson distribution becomes a Bernoulli distribution [18]. A long time period is created using n unit time slots.

Theoretically, wireless recharge is restricted by how quickly the charging coil can transfer energy and the rate at which the battery can absorb this energy. The smaller of the 2 the rate at which the node can be recharged. We make an assumption that the recharging coil can induce enough currents on the receiving node's coil to get it charged. This can be easily achieved using Resonant Inductive Coupling (RIC) based wireless energy transfer. It has the capability of transferring almost 60 Watts of power across at least 2 meters [19]. When the recharging current is appreciably high, the time required to recharge the node depends on the rate at which the battery is able to absorb it.

We use an example of Panasonic NiMH AAA battery (HHR75AAA) to plot the relation between recharge time and battery capacity. The graph is derived with reference to the available curves already provided in the datasheet [16]. The instantaneous Voltage at a time instance t is mapped against the capacity ratio. The resultant function that represents the time required to recharge the node is plotted in Figure 6. Curve fitting in Matlab is used to obtain an approximation function.

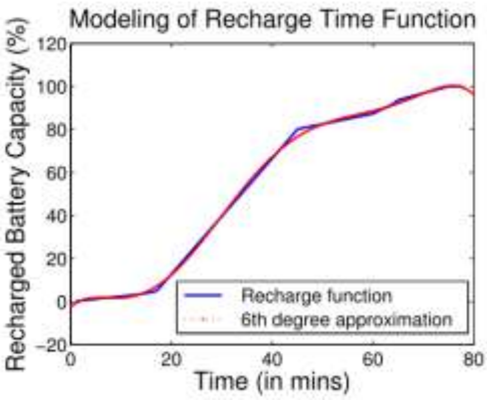

Figure 6: Matlab curve depicting charging of a battery to 100%

The energy neutrality condition is given by the following equation:

$$E_r + E_i \geq E_c \quad \text{... (1)}$$

It says that for a considerably long time duration, on every node in the network, the sum of the Replenished Energy (E_r) and initial energy (E_i) should be at least as big as the energy consumed (E_c). This is condition should mandatorily be achieved for the perpetual operation of the network. During the full recharging time, a SenCar will be able to replenish the battery to its full capacity. Intuitively, we can say that SenCars keep recharging node after node without any idle time in between, and each node has the minimum threshold energy or almost zero energy before being selected for a recharge.

Since it is difficult to analytically calculate the value of E_r, an upper bound can be obtained to provide an estimate that is reasonable enough to derive the total recharge capability of the SenCars.

During n time slots, the total recharged energy for the whole network is the recharge rate, $(C/t_r)S$, times the time duration n (e.g., battery capacity C = 750 mAh for a full recharge, time t_r is 72 mins for a Panasonic Ni-MH, HHR75AAA battery [16]). The average recharged energy E_r is calculated by dividing the total number of nodes N in the wireless sensor network. Thus, the upper bound of E_r is given by:

$$Er = \frac{nCS}{t_r N} \quad \text{… (2)}$$

XII. MODIFIED SENCAR COUNT CALCULATION

Most existing recharging methods available in the market assumes an infinite number of SenCars for recharging the network; however NETWRAP has come up with a minimum fixed number of SenCars that are required to keep the nodes alive in the network. From Eq. (2), we can derive the minimum number of SenCars needed, S.

This is given by the following formula:

$$S = \left\lceil \frac{t_r N(2.33\sqrt{np(1-p)} + np - E_i)}{Cn} \right\rceil. \quad \text{… (3)}$$

Where t_r is the time taken to recharge a battery completely, n is the time duration of recharge, C is the capacity of the battery, N the number of Sensor nodes in the network, working probability p and E_i which is the initial energy available in the node just before recharging. In our proposition the same equation can be used for the number of SenCars however we also need to accommodate a number of SenCar chargers that depends on the number of SenCars N_c, the area spanned by the sensor nodes in the network A and the life time of the SenCar Charger.

XIII. CONCLUSION

The lack of availability of a permanent source of energy near nodes in a WSN has been a trigger into exploring other alternative power sources and ways of connecting them to these nodes in a network. The ultimate goal is to keep the network alive at all times with the least cost that can be achieved. It would have been much easier if we had an option to replace the battery in a node as and when it gets depleted. However the closest we have come is to use a SenCar to energize it from a distance.

In this project, we discussed an enhancement to a SenCar that could be used to introduce the concept of a virtual base station into the wireless sensor network. Because of the ease with which we are able to recharge the SenCars quickly using a SenCar Charger, we have created a near approximation of a readily and easily available power source to keep the network up and running for a greater period of time.

Also since the SenCars need not move back to the Base Station every time they need recharging, their idle time is also reduced to a great extent. Hence we can be assured that this could be a next step towards building a robust recharging framework.

The use of Virtual base station (Figure 4.1.2) illustrates how the distance traversed by data originating from activity detecting nodes by saving transmission steps to reach the Base Station through the other nodes.

Further research in this field includes how security can be enhanced during the communication between a SenCar as a virtual base station and a node if this network is to handle confidential information. More research can also be made in the field where the base station can predict the nodes that need recharge by analyzing the initial traffic report received at the base station.

XIV. References

[1] Thomas Abraham and B.N. Kiran, "A Survey on the Various Frameworks Available for Re-Energizing Wireless Senor Networks", IJRITCC Vol. 3(3) 2015-03, ISSN: 2321-8169.

[2] Lalita Yadav et al, Low Energy Adaptive Clustering Hierarchy in Wireless Sensor Network (LEACH), IJCSIT Vol 5(3), 2014 4661-4664, ISSN: 0975-9646

[3] V Loscri G Morabito and S. Marano, Two Level Hierarchy for Low Energy Adaptive Clustering Hierarchy, DEIS Department, University of Calabria via P.Bucci, 42/c 87036 Rende, CS, Italy

[4] A. Al-zou'bi, Y. Khamayseh, W.Mardini and M.Bani Yassein, Improvement on LEACH Protocol of Wireless Sensor Network (VLEACH)- doi: 10.4156/jdcta.vol3.issue2.yassein

[5] Younis, O. and Fahmy, S. (2004). HEED: A Hybrid, Energy-Efficient, Distributed Clustering Approach for Ad Hoc Sensor Networks. IEEE Transactions on Mobile Computing, 2004, 3(4), 660–669.

[6] Mao YE, Chengfa LI, Guihai CHEN, and Jie WU - An Energy Efficient Clustering Scheme in Wireless Sensor Networks. Ad Hoc & Sensor Wireless Networks, Vol. 3, pp. 99-119

[7] K. Padmanabhan and P. Kamalakkannan, Energy Enhanced Base Station Controlled Dynamic Clustering Protocol for Wireless Sensor Networks – Journal of Advances in Computer Networks, Vol.1 No.1, March 2013

[8] A. Manjeshwar and D. P. Agrawal. TEEN: A Routing Protocol for Enhanced Efficiency in Wireless Sensor Networks.In 1st International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile Computing, April 2001.

[9] Arati Manjeshwar and Dharma P. Agrawal, APTEEN: A Hybrid Protocol for Efficient Routing and Comprehensive Information Retrieval in Wireless Sensor Networks- Center for Distributed and Mobile Computing, ECECS Department,University of Cincinnati, Cincinnati, OH 45221-0030

[10] Dongmin Choi, Sangman Moh, and Ilyong Chung, "ARCS: An Energy-Efficient Clustering Scheme for Sensor Network Monitoring Systems," ISRN Communications and Networking, vol. 2011, Article ID 572572, 10 pages, 2011. doi:10.5402/2011/572572

[11] Cong Wang, Ji Li, Fan Ye and Yuanuan Yang,, NETWRAP: An NDN Based Real-Time Wireless Recharging framework for Wireless Sensor Networks, IEEE Transactions on Mobile Computing, Vol 13, No.6, June 2014

[12] V. Jacobson, D Smetters, J. Thornton, M. Plass, N.Briggs and R.Baraynard, "Networking Named Content", Proc. ACM 5th Int'l Conf. Emergency Networking Experiments and Technologies (CoNEXT) 2009.

[13] S. Bandyopadhyay and E. J. Coyle, "An Energy Efficient Hierarchical Clustering Algorithm for Wireless Sensor Networks," IEEE INFOCOM,April 2003

[14] 14. S.M.Jung ,Y.J.Han, and T.M.Chung "The Concentric Clustering Scheme for Efficient Energy consumption in the PEGASUS 9th International Conf. on Advanced Communication Technology, vol.1, pp.260-265, Feb. 2007.

[15] 15.W.R.Heinzelman,A.Chandrakasan, and H.Balakrishnan "Energy Efficient Communication Protocol for Wireless Sensor Networks" Proceedings of the 33th Hawaii International Conference on System Sciences, 2000.

[16] Panasonic Nickel Metal Hydride Hand book, February 2002, Website: http://www.rosebatteries.com/pdfs/Panasonic_NiMH_Hdbk_02-03_v1.pdf

[17] Y. Wang, M.C. Vuran, and S. Goddard, "Stochastic Analysis of Energy Consumption Wireless Sensor Networks," Proc. IEEE Seventh Ann. Comm. Soc. Conf. Sensor Mesh and Ad Hoc Comm. and Networks (SECON), 2010.

[18] R. Nelson, Probability, Stochastic Processes, and Queuing Theory: The Mathematics of Computer Performance Modeling. Springer,1995.

[19] A. Kurs, A. Karalis, R. Moffatt, J.D. Joannopoulos, P. Fisher, and M. Soljacic, "Wireless Power Transfer via Strongly Coupled Magnetic Resonances," Science, vol. 317, pp. 83-86, 2007

[20] Shobha.K, Mamatha Jadhav.V, Simulation of a Secure Efficient Dynamic Routing In Wireless Sensor Network, IJEAT, ISSN: 2249 – 8958, Volume-2, Issue-5, June 2013

[21] Thomas Abraham and B.N. Kiran, "An Overview on the various Frameworks available for recharging Wireless Sensor Networks",International Journal in IT and Engineering, Vol.03 Issue-04, April,2015, ISSN:2321-1776