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Energy Efficient Utilization Using Clustered Wireless Sensor Network

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ABSTRACT*:In this article,we present a mathematical model to study a multi-sink Wireless Sensor Network (WSN). Both sensors and sinks are assumed to be Poisson distributed in a given finite domain. Sinks send periodic queries, and each sensor transmits its sample to a sink, selected among those that are audible, thus creating a clustered network. Our aim is to describe how the Area Throughput, defined as the amount of samples per unit of time successfully transmitted to the sinks from the given area, depends on the density of sensors and the query interval. We jointly account for radio channel, Physical (PHY), Medium Access Control (MAC) and Network (NET) aspects (i.e., different network topologies, packet collisions, power losses and radio channel behavior), and we compare the performance of two different simple data aggregation strategies. Performance is evaluated by varying the traffic offered to the network (i.e., the density of sensors deployed), the packet size, and, by considering IEEE 802.15.4 as a reference case, the number of Guaranteed Time Slots allocated, and the Super frame Order. The mathematical model shows how the Area Throughput can be optimized.*

Keywords- *Data Aggregation, Area Throughput, Clustered Wireless Sensors, Packet Size, Guaranteed Time Slot*

I. INTRODUCTION

A wireless sensor network (WSN) consists of a large number of sensor nodes deployed over an area and integrated to collaborate through a wireless network. WSNs encourage several novel and existing applications such as environmental monitoring; health care; infrastructure management; public safety; medical; home and office security; transportation; and military. These have been enabled by the rapid convergence of three technologies: digital circuitry, wireless communications, and the micro electro mechanical system (MEMS). These technologies have enabled very compact and autonomous sensor nodes, each containing one or more sensor devices, computation and communication capabilities, and limited power supply. Some of the applications foreseen for WSNs will require a large number of devices in the order of tens of thousands of nodes.

Traditional methods of sensor networking represent an impractical, complex, and expensive demand on cable installation. WSNs promise several advantages over traditional sensing methods in many ways: better coverage, higher resolution, fault tolerance, and robustness. The ad hoc nature and deploy-and-leave vision make it even more attractive in military applications and other risk associated applications, such as catastrophe, toxic zones, and disasters. Performing the processing at the source can drastically reduce the computational burden on application, network, and management. On the other hand, any solution must take into account specific characteristics of this type of network. WSN management must be autonomic, i.e., self-managed (self-organizing, self-healing, self-optimizing, self-protecting, self-sustaining, self-diagnostic) with a minimum of human interference, and robust to changes in network states while maintaining the quality of services.

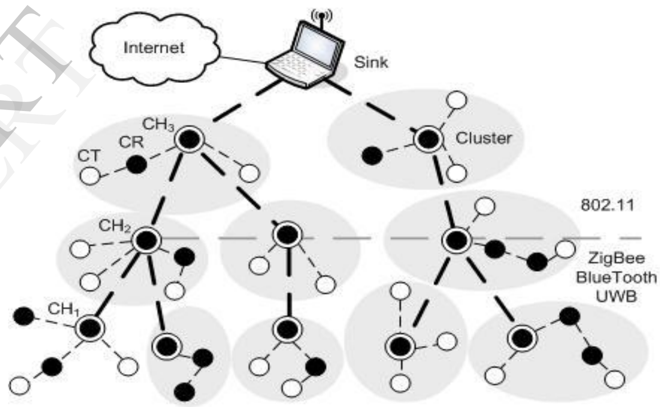

Figure1.example of Clustered Wireless Sensor Network here ZigBee is one of the wireless technology in Sensor Network

Until now, WSNs and their applications have been developed without considering an integrated management solution. The task of building and deploying management systems in environments that will contain tens of thousands of network elements with particular features and organization and that deal with the aforementioned attributes is not trivial. This task becomes more complex due to the physical restrictions of the unattended sensor nodes, in particular energy and bandwidth restrictions.

II SYSTEM DESCRIPITION

2.1 Schemes in WSN:

An infinite area is considered where sensor and sink are uniformly distributed at random. sink forward the collected samples to the fusion center (destination). we select the target based on the finite size without loss of data during transmission.

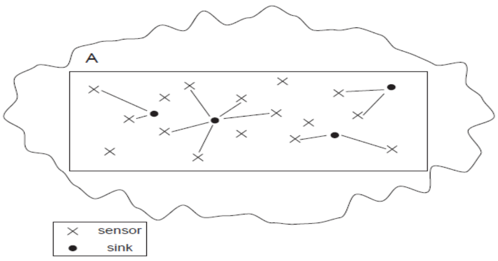

Figure2.Described scenario is considered

2.2 EXISTING SYSTEM

Area Throughput the amount of samples per unit of time originated at the target area and successfully transmitted to a fusion center. According to the characteristics of the observed process, and the area size, the amount of data to be forwarded to the fusion center can be very large. Energy, power, cost and complexity constraints can pose severe limitations to the network design, especially in case of large-scale networks. Hence, simple yet efficient, techniques must be implemented on the network nodes, to maximize the Area Throughput given the network cost, related to the number of sensor nodes deployed

Opportunistic exploitation of the presence of sinks, connected to the infrastructure through any mobile radio interfaces, is an interesting option in some cases. Under these circumstances, many sinks can be present in the monitored space, but their positions are unknown and unplanned; therefore, achievement of a sufficient level of samples is not guaranteed, because the sensor nodes might not reach any sinks (and thus be isolated) owing to the limited transmission range. In such an uncoordinated environment, network connectivity (i.e., the property of making every node able to reach at least one sink) is a relevant issue, and it is basically dominated by the transmission techniques implemented at physical layer (PHY), the wireless medium behavior and the density of sinks: in any case, one would expect that the Area Throughput is larger if the density of sensor nodes is larger

2.2.1 Slotted CSMA-CA protocol

When nodes have to send data or management/control packets during the CAP, they use a slotted CSMA protocol. The protocol contains no provisions against hidden-terminal situations, for example there is no RTS/CTS handshake. To reduce the probability of collisions, the protocol uses random delays; it is thus a CSMA-CA protocol (CSMA with Collision Avoidance).The time slots making up the CAP are subdivided into smaller time slots, called backoff periods. One back off period has a length corresponding to 20 channel symbol times and the slots considered by the slotted CSMA-CA protocol are just these back off periods.

The device maintains three variables NB, CW, and BE. The variable NB count the number of bakeoffs, CW indicates the size of the current congestion window, and BE is the current back off exponent. Upon arrival of a new packet to transmit, these variables are initialized with NB = 0, CW = 2, and BE = mac MinBE (with mac MinBE being a protocol parameter), respectively. The device awaits the next back off period boundary and draws an integer random number r from the interval [0, 2BE − 1]. The device waits for r back off periods and performs a carrier-sense operation (denoted as Clear Channel Assessment (CCA) in the standard). If the medium is idle, the device decrements CW, waits for the next back off period boundary, and senses the channel again. If the channel is still idle, the device assumes that it has won contention and starts transmission of its data packet. If either of the CCA operations shows a busy medium, the number of back offs NB and the back off exponent BE are incremented and CW is set back to CW = 2. If NB exceeds a threshold, the device drops the frame and declares a failure. Otherwise, the device again draws an integer r from [0, 2BE − 1] and waits for the indicated number of back off slots.

2.2.2 Non beaconed mode:

The IEEE 802.15.4 protocol offers a non beaconed mode besides the beaconed mode. Some important differences between these modes are the following:

• In the non beaconed mode, the coordinator does not send beacon frames nor is there any GTS mechanism. The lack of beacon packets takes away a good opportunity for devices to acquire time synchronization with the coordinator.

• All packets from devices are transmitted using an un slotted (because of the lack of time synchronization) CSMA-CA protocol. As opposed to the slotted CSMA-CA protocol, there is no How about IEEE 802.11 and Bluetooth synchronization to back off period boundaries and, in addition, the device performs only a single CCA operation. If this indicates an idle channel, the device infers success.

• Coordinators must be switched on constantly but devices can follow their own sleep schedule. Devices wake up for two reasons:

(i) to send a data/control packet to the coordinators, or

(ii) to fetch a packet destined to itself from the coordinator by using the data request/acknowledgment/ data/acknowledgment handshake (fetch cycle) discussed above. The data request packet is sent through the unslotted CSMA-CA mechanism and the following acknowledgment is sent without any further ado. When the coordinator has a data packet for the device, it transmits it using the unslotted

CSMA-CA access method and the device sends an immediate acknowledgment for the data. Therefore, the device must stay awake for a certain time after sending the data request packet. The rate by which the device initiates the fetch cycle is application dependent.

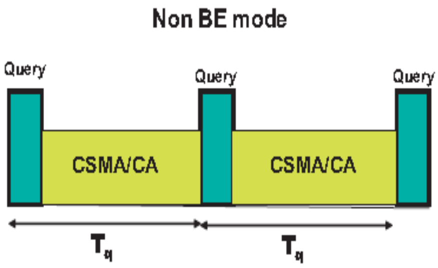

Figure3. Non Beacon-Enabled Mode

2.2.3Network architecture and types/roles of nodes:

The standard distinguishes on the MAC layer two types of nodes:

• A Full Function Device (FFD) can operate in three different roles: it can be a PAN coordinator (PAN = Personal Area Network), a simple coordinator or a device.

• A Reduced Function Device (RFD) can operate only as a device.

A device must be associated to a coordinator node (which must be a FFD) and communicates only with this, this way forming a star network. Coordinators can operate in a peer-to-peer fashion and multiple coordinators can form a Personal Area Network (PAN). The PAN is identified by a 16-bit PAN Identifier and one of its coordinators is designated as a PAN coordinator. A coordinator handles among others the following tasks:

• It manages a list of associated devices. Devices are required to explicitly associate and disassociate with a coordinator using certain signaling packets.

• It allocates short addresses to its devices. All IEEE 802.15.4 nodes have a 64-bit device address. When a device associates with a coordinator, it may request assignment of a 16-bit short address to be used subsequently in all communications between device and coordinator. The assigned address is indicated in the association response packet issued by the coordinator.

In the beaconed mode of IEEE 802.15.4, it transmits regularly frame beacon packets announcing the PAN identifier, a list of outstanding frames, and other parameters. Furthermore, the coordinator can accept and process requests to reserve fixed time slots to nodes and the allocations are indicated in the beacon. It exchanges data packets with devices and with peer coordinators.

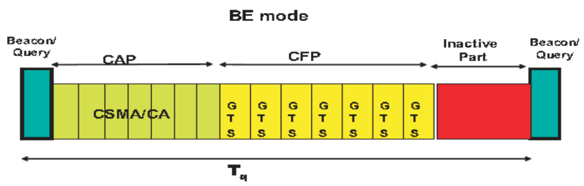

Figure3. IEEE 802.15.4 Beacon Enabled Mode

2.3 PROPOSED SYSTEM:

One option to reduce the need for transmission of large amounts of packets is data aggregation, which consists in accumulating samples at a given node, and transmitting them to the sink through one single packet, possibly of larger size. In this context, we might consider two simple options:

i) Concatenation (i.e., aggregation at sensor level): sensor nodes take and record one sample after each query for a given interval of time, and send all of them in one single batch at the end of the interval;

ii) Aggregation at router level: if multi-hop links are followed by packets to reach the sink, intermediate nodes can process the samples received by separate sensors and aggregate them, to reduce packet payload and duration. With the former technique, delays are introduced, as some samples are queued for several query intervals before being forwarded to the sink;

Although simple, this strategy can be applied only as long as the temporal variation of the observed process is not too considerable. On the other hand, the latter requires exploitation of potential spatial correlations between samples, which requires proper signal processing capabilities. This paper jointly accounts for PHY, MAC, NET and data aggregation issues of clustered WSNs, with the aim of mathematically deriving the conditions for maximization the Area Throughput. A general analytical framework is introduced, covering two separate cases: small networks, where the transmission range of sensors is in the same order of the area side, and large networks where border effects can be neglected thus reducing mathematical complexity. The latter case brings to some interesting discussions.

III. DESIGN TECHNIQUE OVERVIEW:

3.1 .Poisson Distribution:

There are many fundamental problems that arise in the research of wireless sensor networks. Among them one important issue is that of limiting achievable coverage. A point in an area can be detected by a sensor provided the point is within the distant r of the sensor, where r is the sensing radius of the sensor. The area is said to be covered if every point in the area can be detected by a sensor. In the literature there have been several discussions concerning the minimum sensing radius, depending on the numbers of (active) sensors per unit area, which guarantees that the area is covered in a limiting performance. In [12], the authors considered the problem of covering a square of area A with randomly located circles whose centers are generated by a two-dimensional Poisson point process of density D points per unit area. Suppose that each Poisson point represents a sensor with sensing radius R which may depend on D and A.

3.2. IEEE 802.15.4 MAC protocol:

The Institute of Electrical and Electronics Engineers (IEEE) finalized the IEEE 802.15.4 standard in October 2003. The standard covers the physical layer **140** MAC protocols and the MAC layer of a low-rate Wireless Personal Area Network (WPAN). Sometimes, people confuse IEEE 802.15.4 with ZigBee5, an emerging standard from the ZigBee alliance. ZigBee uses the services offered by IEEE 802.15.4 and adds network construction (star networks, peer-to-peer/mesh networks, cluster-tree networks), security, application services, and more. The targeted applications for IEEE 802.15.4 are in the area of wireless sensor networks, home automation, home networking, connecting devices to a PC, home security, and so on. Most of these applications require only low-to-medium bitrates (up to some few hundreds of kbps), moderate average delays without too stringent delay guarantees, and for certain nodes it is highly desirable to reduce the energy consumption to a minimum.

The physical layer offers bitrates of 20 kbps (a single channel in the frequency range 868–868.6 MHz), 40 kbps (ten channels in the range between 905 and 928 MHz) and 250 kbps (16 channels in the 2.4 GHz ISM band between 2.4 and2.485 GHz with 5-MHz spacing between the center frequencies). There are a total of 27 channels available, but the MAC protocol uses only one of these channels at a time; it is not a multichannel protocol. More details about the physical layer can be found in Section 2.1.4.The MAC protocol combines both schedule-based as well as contention-based schemes. The protocol is asymmetric in that different types of nodes with different roles are used, which is described next.

3.3 Super frame structure:

The superframe is subdivided into an active period and an inactive period. During the inactive period, all nodes including the coordinator can switch off their transceivers and go into sleep state. The nodes have to wake up immediately before the inactive period ends to receive the nextbeacon. The inactive period may be void.

The active period is subdivided into 16 time slots. The first time slot is occupied by the beacon frame and the remaining time slots are partitioned into a Contention Access Period (CAP) followed by a number (maximal seven) of contiguous Guaranteed Time Slots (GTSs).

The length of the active and inactive period as well as the length of a single time slot and the usage of GTS slots is configurable.The coordinator is active during the entire active period. The associated devices are active in the GTS phase only in time slots allocated to them; in all other GTS slots they can enter sleep mode.

In the CAP, a device can shut down its transceiver if it has neither any own data to transmit nor any data to fetch from the coordinator. It can be noted already from this description that coordinators do much more work than devices and the protocol is inherently asymmetric. The protocol is optimized for cases where energy constrained sensors are to be attached to energy-unconstrained nodes.

3.4 Data transfer procedures:

Let us first assume that a device wants to transmit a data packet to the coordinator. If the device has an allocated transmit GTS, it wakes up just before the time slot starts and sends its packet immediately without running any carrier-sense or other collision-avoiding operations. However, the device can do so only when the full transaction consisting of the data packet and an immediate acknowledgment sent by the coordinator as well as appropriate InterFrame Spaces (IFSs) fit into the allocated time slots. If this is not the case or when the device does not have any allocated slots, it sends its data packet during the CAP using a slotted CSMA protocol, described below.

The coordinator sends an immediate acknowledgment for the data packet. The other case is a data transfer from the coordinator to a device. If the device has allocated a receive GTS and when the packet/acknowledgment/IFS cycle fits into these, the coordinator simply transmits the packet in the allocated slot without further coordination.

The device has to acknowledge the data packet.The more interesting case is when the coordinator is not able to use a receive GTS. In fact, the device's address is included as long as the device has not retrieved the packet or a certain timer has expired. When the device finds its address in the pending address field, it sends a special data request packet during the CAP. The coordinator answers this packet with an acknowledgment packet and continues with sending the data packet. The device knows upon receiving the acknowledgment packet that it shall leave its transceiver on and prepares for the incoming data packet, which in turn is acknowledged. Otherwise, the device tries again to send the data request packet during one of the following superframes and optionally switches off its transceiver until the next beacon.

IV.EVALUATION OF THE AREA THROUGHPUT

4.1 Probability of Successful Transmission:

Let us consider an arbitrary sensor node located in A, and denote its position as (x, y) with respect to a reference system with origin centered in A. We aim at computing the probability that the node can connect to one of the sinks in the area and successfully transmit its data sample. To this aim, we define Ps|K(x, y) as the probability of successful transmission conditioned on the overall number, K, of sensors in the area. This probability can be computed by averaging Ps(x, y) of over the number of nodes, n, associated to a sink. The dependence on (x, y), previously not emphasized to avoid complex notations, is due to the well-known border effects in connectivity [19].

Ps|K(x, y) = En{Ps(x, y)}
= En{PNET (n) · PCON−ST (x, y)}
(1)
= En{PNET (n)} · PCON−ST (x, y).
(2)

In Orrisset *al.* showed that the number of sensors uniformly distributed on an infinite plane that hear one particular sink as the one with the strongest signal power (i.e., the number of sensors competing for access to such sink) is
Poisson distributed with mean

$$\overline{n} = \mu_s \frac{1 - e^{-\mu_{sink}}}{\mu_{sink}}$$
(3)

Where µsink= ρ0Aσ = IAσ/A is the mean number of audible sinks on an infinite plane from any position ; µs= ρsAσis the mean number of sensors that are audible by a given sink. Such a result is relevant toward our goal even though it was derived on the infinite plane. In fact, n can still be considered Poisson distributed even inside a finite area. The only two things that change are:

• nis upper bounded by K (i.e., the pdf is truncated);
• the density ρsis to be computed as the ratio K/A [m−2],

thus yielding µs= KAσ
Therefore, we assume n ∼ Poisson(¯n), with

$$\overline{n} = \overline{n}(K) = K\frac{A\sigma}{A}\frac{1 - e^{-\mu_{sink}}}{\mu_{sink}} = K\frac{1 - e^{-\frac{I_{A\sigma}}{A}}}{I}$$
(4)

By making the average in (8) explicit, we get

$$P_{\frac{S}{K}(x,y)} = P_{CON-ST}(x,y).\frac{1}{M}\sum_{j=1}^{K} P_{NET(j)}\frac{\overline{n}^j e^{-\overline{n}}}{j!}$$
(5)

Where M is a normalizing factor.

4.2 Area Throughput:

The average number of samples per query that can be generated by the network is given by the mean number of sensors in A, ¯K. Now denote by Gthe average number of samples that can be generated per unit of time, given by

$$G = \widehat{K}.f_q = \rho_s.A.\frac{1}{T_q}[\text{samples/sec}]$$
(1)

The most interesting case is when border effects can be negligible (large scale networks). and equation may be rewritten as

$$S = \frac{(1 - e^{-\frac{I_{A\sigma}}{A}})}{T_q}\sum_{j=1}^{+\infty}\frac{\sum_{j=1}^{k} P_{NET(j)}\frac{\overline{n}^j e^{-\overline{n}}}{j!}}{\sum_{j=1}^{k}\frac{\overline{n}^j e^{-\overline{n}}}{j!}}.\frac{(GT_q)^k e^{-GT}{}_q}{(K-1)!}$$
(2)

This result can be approximated to

$$S \approx G\left(1 - e^{-\frac{I_{A\sigma}}{A}}\right).\sum_{j=1}^{\infty+} P_{NET(j)}\frac{\overline{N}^j e^{-\overline{N}}}{j!}$$
(3)

The numerical results will show that expression approximates very well , even for small values of G, while being much simpler to compute. Moreover, allows further elaborations.

V. OPTIMUM AVAILABLE AREATHROUGHPUT

By using the value of G which yields the maximum value of S, denoted as Gm hereafter, can be evaluated by computing the derivative of S with respect to G. The value of Gm is relevant because it determines the number of sensors to deploy in A to maximize the Area Throughput.

By computing such derivative, one gets easily to the following equation:

$$\sum_{j=1}^{\infty+} P_{NET(j).(1+j)}.\frac{\overline{N}^j e^{-\overline{N}}}{j!} = \sum_{j=1}^{\infty+} P_{NET(j).(\overline{N})}.\frac{\overline{N}^j e^{-\overline{N}}}{j!}$$
(1)

where in this case ¯N = GmTq(1 − e−IAσ/A)/I.

Even though the numerical computation of the value Gm requires the specific knowledge of PNET (n), some interesting considerations can be done. Expression (22) depends on Gm only through ¯N . Therefore, the equality holds for a given value of ¯N ; let us denote such (unknown) value as Y . Consequently, GmTq(1−e−IAσ/A)/I = Y , and therefore Gm = Y ·I Tq(1−e−IAσ/A).

In words, the optimum value of G is proportional to the product of the average number of sinks in the area and PCON. Further more, by substituting Gm=Y·I Tq(1−e−IAσ/A) in , the maximum value of the Area Throughput, denoted as Sm, is shown not to depend on PCON. Finally, the most interesting result that can be achieved through this approximated analysis stands in the behavior ofthe S versus G curves for G tending to infinity. In fact, by assuming PNET (n) = 1/n and letting G tend to infinity, expression (21) brings to S = I/Tq. It can be shown that if the tail of the PNET (n) function is heavier than 1/n (e.g., it goes like 1/n2), for G tending to infinity, expression brings to S = 0. Therefore, if the MAC and network topology are chosen such that the tail of the PNET (n) function is lighter than 1/n or, for large n, it follows a 1/n law, then the Area Throughput has an horizontal asymptote when G is large; increasing the density of sensors, S does not reach zero and the network behavior is more stable.

$$S \approx \frac{(1-e^{\frac{-I_A\sigma}{A}})}{T_q}\sum_{j=1}^{+\infty}\frac{\sum_{j=1}^{+\infty} P_{NET(j)}\frac{\overline{N}^j e^{-\overline{N}}}{j!}}{1-e^{-\overline{N}}}.k.\frac{(GT_q)^k e^{-GT}{}_q}{K!}$$

(2)

VI. ENERGY CONSUMPTION IN WSN:

6.1 power-aware protocol stack:

The protocol stack used by sensor nodes is shown in Figure 1; much research has been done to design schemes for power conservation and power management in sensor nodes upon all layers of protocol stack, as studied in subsequent sections.

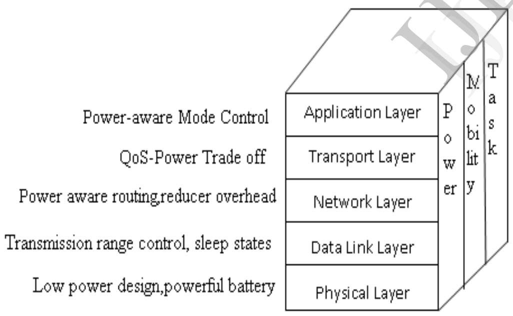

Figure 4: Cross-layer optimization on sensor networks protocol stack

6.2Power-Aware Physical Layer:

Many physical layer modulation schemes reduce the radio-transceiver power consumption by reducing transmission time. But transmission energy can also be reduced by lowering transmission power and increasing transmission duration. Transmission energy does not monotonically decrease as transmission time increases. Transmission energy may increase when transmission time exceeds some threshold value. Higher modulation levels may be unrealistic in WSNs but for peak-throughput, higher modulation levels are required. More energy can be conserved by dynamically adopting the modulation level according to instantaneous traffic load, known as modulation scaling. Multiple frequency-shift keying is more energy efficient than other M-ary or binary modulation schemes for short range, low duty communication systems, like WSNs

6.3 Powers-Aware Data Link Layer:

The data link layer includes Medium Access Control and error control protocols. MAC protocol in a self organizing WSN creates network infrastructure by defining appropriate communication channels, and shares available communication media among nodes. Since transmission is the most energy- consuming task in a sensor node, MAC protocols should be properly designed to offer energy saving opportunities by cutting down energy inefficient access to minimum. A sensor node wastes a large amount of energy due to idle-listening of channel, packet collision, overhead of control packets, and overhearing. In collision and idle-listening, the node continuously consumes energy in retransmission and sensing channels respectively. Therefore, energy efficient MAC protocol must avoid collision, overhearing, overhead of control packets, and idle-listening.

6.4 POWER-AWARE NETWORK LAYER:

Network layer is responsible of topology control, layer 3 addressing, and making routing decisions. Depending upon node versatility, network can adopt directed, multi-hop, single-hop clustering, or multi-hop clustering transmission schemes. Type of transmission scheme supported by protocol depends upon its functionality.

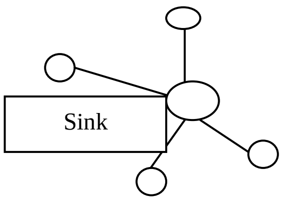

Figure 5: (a)Directed

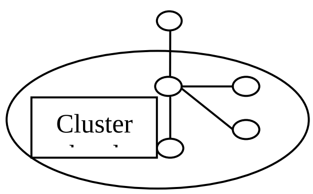

Figure 6: (c)Single-hop Cluster

VII. PERFORMANCE EVALUATION:

In this We take domain of area $A=500[m^2]$ and S as a function of G is in NonBecon Enabled Mode is employed. In this small network case we can evaluate the of border effects on connectivity.

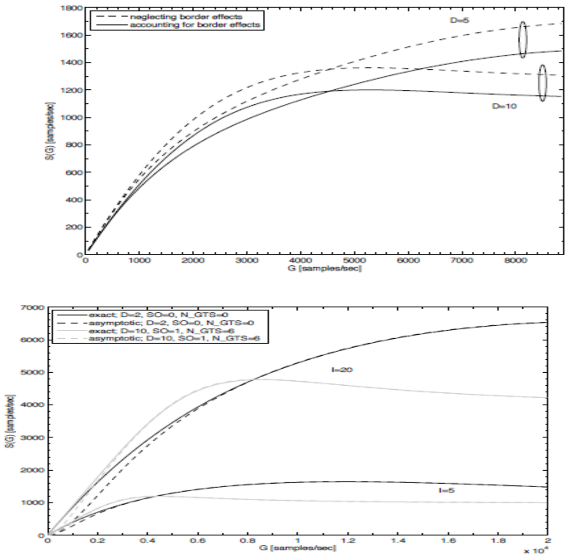

Figure 7: Performance Evolution of Area in Small Network.

The accuracy of the asymptotic model derived against the exact one. when i=20 through put is higher because the greater number of clusters are formed and hence the small number of nodes are competing for channels access in each them.

VIII. ASSUMPTION OF EXPERIMENTAL RESULTS:

The Screen shot below shows the structure in which the sensors are placed in the specific places and PAN initiate the sensors deployed in the specific places.

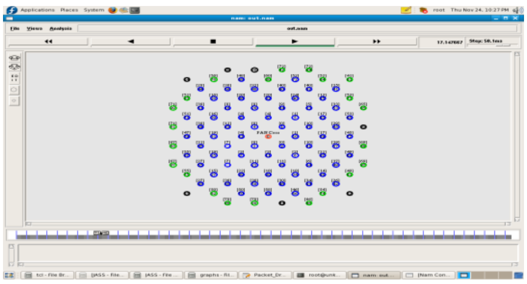

Figure 8:Sensor Placement

8.1 Cluster Formation:

The below screen shot shows the Cluster formation of the sensors placed in the specific places and monitor the movement of the object in clustered area and reduce the power consumption of the sensor.

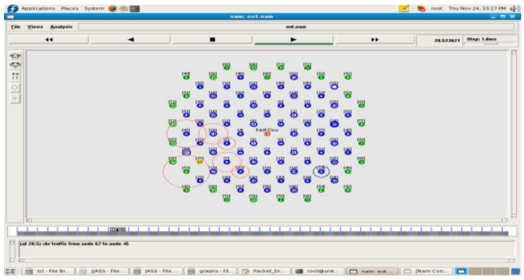

Figure 9:Cluster Formation

8.2 Simulation Time Vs Throughput:

The below screen shot shows the Comparison of the Area Throughput Vs Simulation Time.In the graph above line denotes the available area proposed throughput and below line indicates the existing throughput.

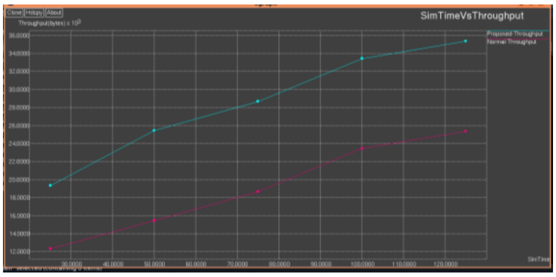

*Figure 10:*Simulation Time based on Throughput

8.3 Energy Consumption of WSN :

The below screen shot shows the Comparison of the Average Energy Consumed by sensors Vs Simulation Time. The above graph shows the energy consumption of sensor in the particular area. Energy consumption is calculated

By using cluster network energy consumption of sensor is low. Without cluster energy consumption is high.

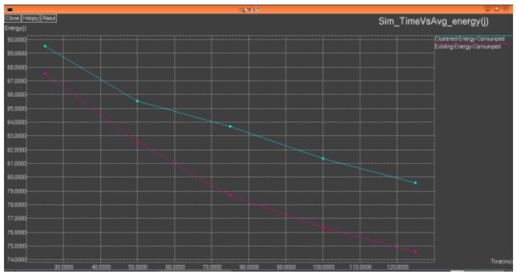

Figure11. Energy Consumption of WSN

IX. CONCLUSION:

In this paper a mathematical framework to determine the maximum Area Throughput of a WSN designed for temporal/ spatial random process estimation, has been determined, accounting for radio channel, PHY, MAC and NET protocol layers, and simple data aggregation techniques. The algorithms and techniques considered are simple: this is a plus in WSN environments where network deployment cost should be minimized.

The use of mathematical approaches permits the derivation of some conclusions which might be very useful to drive the selection of algorithms, such as the impact of MAC behavior on the overall performance, or the role played by separate types of data aggregation techniques (at the sensor or router level).Energy consumption is, for many applications of WSNs, by using clustered wireless sensor network energy consumption of the sensor to be reduced.

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