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Path Planning for Time-Constrained Data Gathering in Wireless Sensor Networks Using Mobile Nodes

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Abstract: We consider the problem of gathering data from a sensor network using mobile elements. The goal is to plan the paths for the mobile elements that minimize the total length travelled. We propose an algorithmic solution that builds node disjoint tours that always include the sink, cover the network, and optimize the total length travelled. We provide an integer linear programming formulation for the problem, and propose two novel heuristics for building the tours. We evaluate the performance of our algorithm by comparing it to the optimal solution as well as to an alternative heuristic, commonly used in related time-window vehicle routing problems, and demonstrate the superior performance of our approach.

Keywords: Wireless sensor network (WSN), WIMAX technology, novel heuristics, Wireless Distribution System (WDS).

I. INTRODUCTION

In the evolving of Wireless Technology the system designers are faced with a challenging set of problems that stem from access mechanisms, energy conservation, a required low error rate, transmission speed characteristics of the wireless links and mobility aspects such as small size, light weight long battery life and low cost. Flexibility of the mobile terminal can be defined on two levels. First at the level of system operation, flexibility can be defined as the ability of the mobile terminal to support many modes of operation e.g., voice, audio, video, web browsing, GPS, data transmission etc while using the same limited set of hardware. Second at the communication link level, flexibility can be defined as the ability of the mobile device to operate freely in the wireless sensing field. We consider the problem of gathering data from a sensor network using mobile elements. In particular, we consider the case where the data are produced by measurements and need to be delivered to a predefined sink within a given time interval from the time the measurement takes place. Mobile elements travel the network in predefined paths, collect the data from the nodes, and deliver them to the sink. Each node must be visited by a mobile element that must then reach the sink within the given time constraint. The goal is to plan the paths for the mobile elements that minimize the total length travelled. Several variations of this problem have been considered in existing literature.

Major goal is to provide the energy efficient data path planning for the mobile system. This paper is to develop the Wireless Distributive System Management with high quality, reliability, mobility and routing. The choice of implementing algorithm depends upon the power all allocation, nodal analysis, data gathering and node localization.

We propose an algorithmic solution that builds node disjoint tours that always include the sink, cover the network, and optimize the total length travelled. Integer Linear Programming is formulated for the problem, two novel heuristics for building the tours are considered. We evaluate the performance of our algorithm by comparing it to the optimal solution as well as to an alternative heuristic, commonly used in related time-window vehicle routing problems, and demonstrate the superior performance of our approach.

The primary objective of this work is to provide a reliable architecture for the mobile system in the WIMAX technology. The Design and Simulation will be based on the principles and methods of Energy Efficient Data Gathering. This is performed in MATLAB simulation. The system will reflect the low cost requirement of the future systems and at the same time it will combine low power consumption with an efficient performance. The Final System will provide a better solution for Channel Changes with efficient Data Gathering. Another important goal of this work is to develop the bases for the Relaying methods in wireless Sensor Network.

A. Wireless Distribution System

A Wireless Distribution System (WDS) is a system that enables the wireless interconnection of access points in an IEEE 802.11 network. It allows a wireless network to be expanded using multiple access points without the need for a wired backbone to link them, as is traditionally required. The notable advantage of WDS over other solutions is that it preserves the MAC addresses of client frames across links between access points. An access point

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can be either a main, relay, or remote base station. A main base station is typically connected to the wired Ethernet. A relay base station relays data between remote base stations, wireless clients or other relay stations to either a main or another relay base station. A remote base station accepts connections from wireless clients and passes them on to relay or main stations. Connections between "clients" are made using MAC addresses rather than by specifying IP assignments.

All base stations in a Wireless Distribution System must be configured to use the same radio channel, method of encryption (none, WEP, or WPA) and the same encryption keys. They may be configured to different service set identifiers. WDS also requires that every base station is configured to forward to others in the system.WDS may also be referred to as repeater mode because it appears to bridge and accept wireless clients at the same time (unlike traditional bridging). However, with this method, throughput is halved for all clients connected wirelessly.WDS can be used to provide two modes of wireless AP-to-AP connectivity: Wireless Bridging in which WDS APs communicate only with each other and don't allow Wireless clients or Stations (STA) to access them. Wireless Repeating in which APs communicate with each other and with wireless STAs.

The sensor nodes that are far away from the path will need to transmit their data to the mobile element at higher power levels and thus use up their energy budget more quickly. For WSNs that rely on their entire sensor nodes for normal operations, such uneven energy depletion will lead to limited lifetime of WSNs. Different from the existing single-path solutions, in our preliminary study, we have proposed the idea of exploiting multiple paths for the mobile element in WSNs to extend the WSN's lifetime.

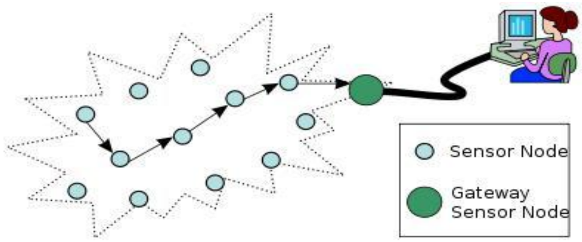

Figure 1: Typical Multi-hop Wireless Sensor Network Architecture

Wireless Sensor Networks (WSN) having large number of sensor nodes which will cover the earth in time to come. Sensor Networks covering vast areas are already in the wild and are instrumental in ways not possible using pre-existing technology. The most important resource on these nodes is the energy supply and in almost all the cases a battery in the node is responsible for supplying energy for the entire lifetime of the node. The deployment of nodes could be at inaccessible locations and hence once the battery has drained the node is unusable for the network. Increasing the lifetime of the node becomes a very important factor to bring the technology mainstream. The biggest advantage in case of WSN is also their biggest limitation, the unconnected nature of the network also limits the life time of the network. Energy whole problem limits the total life time by disconnecting the network from the base node. For many WSN implementations it is practical to have a mobile base node, where a mobile base node traverses through the nodes on land or in air to collect data. Instead of communicating to each and every node the energy consumption can be decreased by using dynamic routing protocols developed for Ad hoc networking. Maintain a constant path for all the traversals of the base node is equally bad since even this will result in the formation of energy holes in the network. Generating a different path for each traversal with node energy as constraint will provide an equilibrium in energy consumption hence giving to the WSN. For the purpose of simulation the network is maintained within the following constrains. Sensor nodes are distributed over a large area and may or may not have a layout in distribution. The distance between two nodes is not greater than the communication range of the nodes and does not interfere with the formation of the network. Individual nodes do not communicate to the base unit instead in a neighborhood a single node acts as an agent between the nodes and the base unit. A mobile base unit is responsible for retrieval of data. Number of sensor nodes is limited and known, for larger number of nodes the heuristics will have to be updated.

II. PROPOSED SYSTEM

To maximize network coverage and to provide a reliable, energy-efficient monitoring depends on selecting minimum number of sensors in active mode to cover all the targets. So this power saving technique can be regarded as Set Covering Problem (SCP). Designing for a minimum set of nodes where node selection procedure is based on the energy of each node in a set, provide energy-efficient sensor network. The performance analysis through simulation results show that the algorithm proposed in this selects less working nodes than the other algorithms and maximize the network lifetime as well.

A. Proposed Energy Efficient Algorithm

Energy saving is a paramount concern in wireless sensor networks (WSNs). A strategy for energy saving is to cleverly manage the duty cycle of sensors, by dynamically activating different sets of sensors while non-active nodes are kept in a power save mode. We propose a simple and efficient approach for selecting active nodes in WSNs. Our primary goal is to maximize residual energy and application relevance of selected nodes to extend the network lifetime while meeting application-specific QOS requirements. We formalize the problem of node selection as a knapsack problem and adopt a greedy heuristic for solving it. An environmental monitoring application is chosen to derive some specific requirements. Analyses and simulations were performed and the impact of various parameters on the process of node selection was investigated. Results show that our approach out performs for node selection, achieving large energy savings while preserving QOS requirements.

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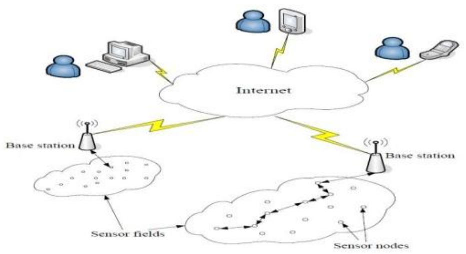

Figure 2: Accessing WSN

III. WORKING PRINCIPLE

Wireless sensor network (WSN) is a collection of physically distributed sensing devices that can communicate through a shared wireless channel. Individual nodes do not communicate to the base unit instead in a neighborhood a single node acts as an agent between the nodes and the base unit. Consider user1, user2, BS1, BS2, and no of relay stations (RS).When user1 make a call to user2 it will transfer through BS1, number of RS, BS2 and then to user2. In BS1 call request from user1 to user2 is processed and transferred to BS2 through various RS (in case of long distance). Once call connected loop will formed between user1 to user2 through BS the energy of the signal is maintained at each stage.

Instead of communicating to each and every node the energy consumption can be decreased by selecting the energy efficient path with less time delay and shortest distance. To maximize throughput without consuming much more power of nodes MIMO is used. To select the Energy efficient nodes SVD algorithm (H = U.S.V*) is proposed. The Capacity of each nodes is calculated using Shannon Formula (C = log2 (1+(S/N)). Power Allocation Technique (water filling algorithm) is performed to monitor the energy consumed. Data transmitted through the minimum power and maximum capacity node. Selecting a minimum number [of any size set] of these sets so that the sets you have picked contain all the elements that are contained in any of the sets in the input. Additionally, the cost of the sets should also be minimized. This approach is called Set Covering Problem. The parameter q gives weight based on the number of clusters, or closed sets of connected vertices, including isolated points. The q = 1 case is identical to the percolation model, if q > 1 prefers more clusters and if q < 1 fewer are preferred. This technique is called Clustered Random Model.

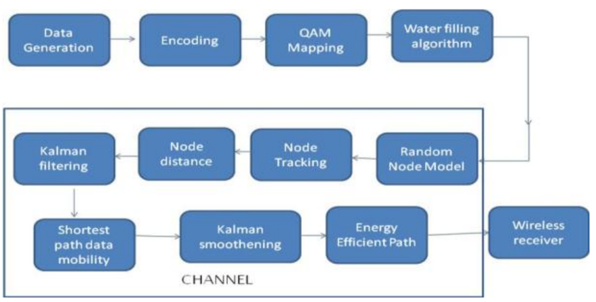

Figure 3: Block Diagram

The major aim is to perform Energy Efficient Data Gathering from all Nodes to the Sink with less time delay and max distance coverage.

A. Node Localization

Node localization is the problem of determining the geographical location of each node in the system. Localization is one of the most fundamental and difficult problems that must be solved for WSN. Localization is a function of many parameters and requirements potentially making it very complex.

For example, issues to consider include: the cost of extra localization hardware, do beacons (nodes which know their locations) exist and if so, how many and what are their communication ranges, what degree of location accuracy is required, is the system indoors/outdoors, is there line of sight among the nodes, For some combination of requirements and issues the problem is easily solved. If cost and form factor are not major concerns and accuracy of a few meters is acceptable, then for outdoor systems, equipping each node with GPS is a simple answer.

If the system is manually deployed one node at a time, then a simple GPS node carried with the deplorer can localize each node, in turn, via a solution called Walking GPS. While simple, this solution is elegant and avoids any manual keying in the location for each node. Most other solutions for localization in WSN are either range-based or range- free. Range-based schemes use various techniques to first determine distances between nodes (range) and then compute location using geometric principles. To determine distances, extra hardware is usually employed, e.g., hardware to detect the time difference of arrival of sound and radio waves. This difference can then be converted to a distance measurement.

In range-free schemes distances are not determined directly, but hop counts are used. Once hop counts are determined, distances between nodes are estimated using an average distance per hop, and then geometric principles are used to compute location. Range- free solutions are not as accurate as range-based solutions and often require more messages. However, they do not require extra hardware on every node.

B. Power Allocation

Starting at the root since there is no broadcasting as in RBS, TPSN is expensive. A key attribute of this protocol is that the timestamps are inserted into outgoing messages in the MAC layer thereby reducing non-determinism. Accuracy is in the range of few microseconds. In FTSP, there are radio-layer timestamps, skew compensation with linear regression, and periodic flooding to make the protocol robust to failures and topology changes. Both transmission and reception of messages are time stamped in the radio layer and differences are used to compute and adjust clock offsets.

Accuracy is in the range of 1-2 microseconds. Considerations in using a clock synchronization protocol include choosing the frequency of resynchronization, determination if clock drift between synchronization times is required, how to handle the multi hop/network problem,

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and minimizing overhead costs in terms of energy and added network congestion.

C. Water Filling Algorithm

The water- filling technique gives three different kinds power allocation depending on the SNR. At low SNR the Water filling technique finds the largest Eigen values to H and sends the entire power trough one single mode (channel). At this level of SNR the increase of capacity is almost linear and increases with 1bit/s/Hz for every 3dB increase of PT power. At intermediate SNR the water-filling technique uses L number of modes where 1<L<min (nT, nR). At this level of SNR the capacity is almost linear and increases with L bit/s/Hz for every 3dB increase of PT . At high SNR the water- filling technique uses all min (nT ,nR) modes for transmission. At this level of SNR the capacity is almost linear and increases with min (nT ,nR) bit/s/Hz for every 3dB increase of PT .

The capacity is calculated for four different nodes (transmit) power distributions. That is Uniform power distribution, the Water filling technique and beam forming is used. In addition to the above three cases the capacity when the mutual coupling effect has been compensated for has also been calculated for each power input distribution.

D. Kalman Filter

A properly designed Kalman Filter allows one to observe only a few quantities, or measured outputs, and then reconstruct or estimate the full internal state of a nodal system. It also provides filtering functions and amplification and can be constructed to provide temperature compensation, common mode rejection, zero offset correction throughout the node. Generate a linear dynamic model. Because Wireless Sensor Network is a set of small and low-cost devices equipped with different kind of sensors. So the each node should be decentralized. Kalman filter is a linear optimal filtering approach, to address the problem when system dynamics become nonlinear; researchers develop sub-optimal extensions of Kalman filter. The discrete-time Kalman Filter, useful for DSP using microprocessors, is a dynamical filter where the sensed outputs are in a vector Zk, the control inputs to the system being observed are in vector Uk, and the estimates of the internal states are given by the vector Xk.
Note that the number of sensed outputs can be significantly less than the number of states one can estimate. The energy efficient nodes are calculated using the equation,

$$X\hat{}k+1=A(I-KH)X\hat{}k + BUk+ AKZK \qquad \dots (5.1)$$

In this filter, matrices A and B represent the known dynamics of the sensed system, and the sensed outputs are given as a linear combination of the states by

$$Zk=HXk \qquad \dots (5.2)$$

Where H is a known measurement matrix.
The Kalman gain K is determined by solving a design equation known as the Equation. The Kalman Filter is the optimal linear estimator given the known system properties and prescribed corrupting noise statistics. The data can be mobile through the nodes without loss in energy.

E. Nodal Analysis

Using singular value decomposition (SVD), the channel matrix H can be decomposed into a product of three matrices as follows

$$H=U.S.V^* \qquad \dots (5.3)$$

Where U are a unitary matrix of dimension nR × nR , V are also a unitary matrix of dimension nT × nT , and S is a nR × nT matrix whose elements are all zero except for the diagonal where there will be min(nT ,nR) of the H matrix Eigen values. The V* represents the complex conjugate transpose of the matrix V. The three matrices corresponds to three different Steps,

F. Projection into TXR Eigen Modes

Each of the first min (nT ,nR) columns in V is a unit-norm vector corresponding to each of the transmit Eigen modes. The relative phases and amplitudes between transmit elements required to excite each Eigen mode are described by each of these column vectors. The first min (nT ,nR) components of the vector V1 are therefore the projection of the transmit vector x into the transmit eigenvector subspace. When the remaining nT > nR, components belong to the subspace orthogonal to the transmit Eigen vector subspace and cannot influence the received vector.

Weighting by Singular Values

Each of the min (nT ,nR) components corresponding to the transmit Eigen Modes are weighted by its associated singular value contained in the main diagonal of the matrix S.

Mapping into RXR Eigen Modes

Each of the first min (nT ,nR) columns in U is a unit-norm vector corresponding to the mapping of each Eigen mode in the receiving space. The remaining N-min (nT ,nR) vectors are not Rx Eigen Modes because they cannot be excited by the transmitter.

Data Gathering

A canonical environmental data gathering application is one where a research scientist wants to collect several sensor readings from a set of points in an environment over a period of time in order to detect trends and interdependencies. This scientist would want to collect data from hundreds of points spread throughout the area and then analyze the data offline.
The scientist would be interested in collecting data over several months or years in order to look for long-term and seasonal trends. For the data to be meaningful it would have to be collected at regular intervals and the nodes would remain at known locations. At the network level, the environmental data gathering application is characterized by having a large number of nodes continually sensing and transmitting data back to a set of base stations that store the data using traditional methods.

These networks generally require very low data rates and extremely long lifetimes.

In typical usage scenario, the nodes will be evenly distributed over an outdoor environment. This distance between adjacent nodes will be minimal yet the distance across the entire network will be significant. After deployment, the nodes must first discover the topology of the network and estimate optimal routing strategies. The routing strategy can then be used to route data to a central collection points. In environmental monitoring applications, it is not essential that the nodes develop the optimal routing strategies on their own. Instead, it may be possible to calculate the optimal routing topology outside of the network and then communicate the necessary information to the nodes as required. This is possible because the physical topology of the network is relatively constant. While the time variant nature of RF communication may cause connectivity between two nodes to be intermittent, the overall topology of the network will be relatively stable.

Environmental data collection applications typically use tree-based routing topologies where each routing tree is rooted at high-capability nodes that sink data. Data is periodically transmitted from child node to parent node up the tree-structure until it reaches the sink. With tree-based data collection each node is responsible for forwarding the data of all its descendants. Nodes with a large number of descendants transmit significantly more data than leaf nodes. These nodes can quickly become energy bottlenecks. Once the network is configured, each node periodically samples its sensors and transmits its data up the routing tree and back to the base station. For many scenarios, the interval between these transmissions can be on the order of minutes. Typical reporting periods are expected to be between 1 and 15 minutes; while it is possible for networks to have significantly higher reporting rates. The typical environment parameters being monitored, such as temperature, light intensity, and humidity, does not change quickly enough to require higher reporting rates. In addition to large sample intervals, environmental monitoring applications do not have strict latency requirements. Data samples can be delayed inside the network for moderate periods of time without significantly affecting application performance. In general the data is collected for future analysis, not for real-time operation.

In order to meet lifetime requirements, each communication event must be precisely scheduled. The senor nodes will remain dormant a majority of the time; they will only wake to transmit or receive data. If the precise schedule is not met, the communication events will fail. As the network ages, it is expected that nodes will fail over time. Periodically the network will have to reconfigure to handle node/link failure or to redistribute network load. Additionally, as the researchers learn more about the environment they study, they may want to go in and insert additional sensing points. In both cases, the reconfigurations are relatively infrequent and will not represent a significant amount of the overall system energy usage. The most important characteristics of the environmental monitoring requirements are long lifetime, precise synchronization, low data rates and relatively static topologies.

Power Loss and Maximum Capacity of Nodes

The discussion above leads to some interesting conclusions:
If $nT > nR$, some power is wasted on exciting a subspace orthogonal to the receiver. The receiver cannot interpret this subspace and it's totally unnecessary.
If the power is allocated uniformly over the transmitter there will be an average power loss of
$10\log(nT/nR)$ … (5.4)
If $nT \leq nR$, –– there is no power loss. There will be $nR - nT$, dimensions in the receiver space, which are not excited by the receiver Eigen vectors.
The channel is estimated in the receiver through to use of a short known transmitted training sequence. For a one-antenna system one can apply the Shannon formula: $C=\text{Log}2\ (1+S/N)$
Where C is the channel and is measured in [Bits/ (sec*Hz)], B is the bandwidth and S/N is the signal-to-noise ratio. This is the maximum rate the channel can give with arbitrary low probability of bit errors.

IV. SIMULATION RESULTS

Generate random binary sequence of +1's and -1's. Group them into pair of two symbols. Code it per the antenna, multiply the symbols with the channel and then add white Gaussian noise. Equalize the received symbols. Perform hard decision decoding and count the bit errors. Repeat for multiple values of Eb / N0 and plot the simulation and theoretical results. To select the Energy efficient nodes SVD algorithm (H= U.S.V*) is proposed. N-min (nT , nR) vectors are RX Eigen Modes excited by the transmitter. Each node should have Kalman filter which is a linear optimal filtering approach which helps in node mobility management and node tracking.

A Kalman filter combines available measurement data, plus prior knowledge about the system and measuring devices, to produce an estimate of the desired variables in such a manner that the error is minimized statistically.

The Capacity of each nodes is calculated using Shannon Formula (C=log2 (1+(S/N)). Distance Learning Algorithm and Time Delay Estimation are performed in MATLAB simulation.

It tells about the performance analysis of this proposed algorithm ensures its effectiveness thereby providing Efficient Mobility, Low cost, higher bandwidth, maximum distance coverage, Low Bit error rate, High Signal to Noise ratio, Reduced ISI, High Data Rate simulated in MATLAB. These are the process done in that MATLAB

Simulation Work and their results are furnished below:

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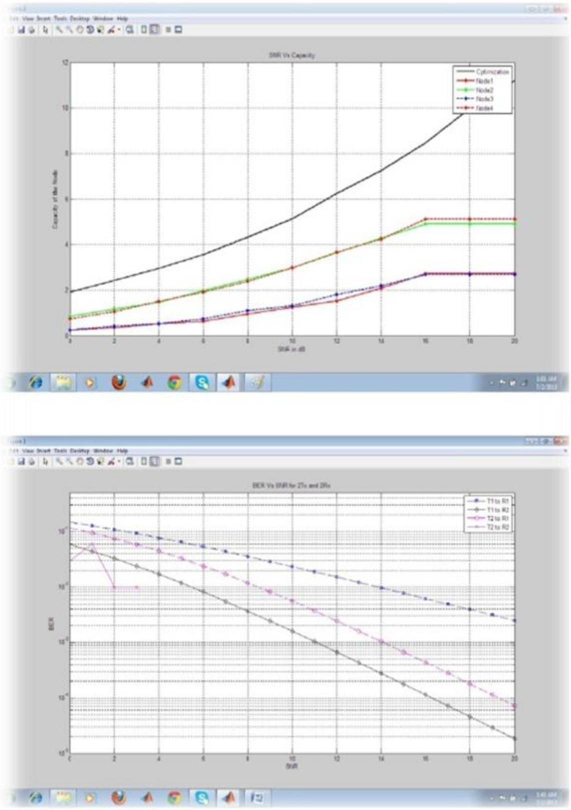

Figure 4: Optimization of Nodes

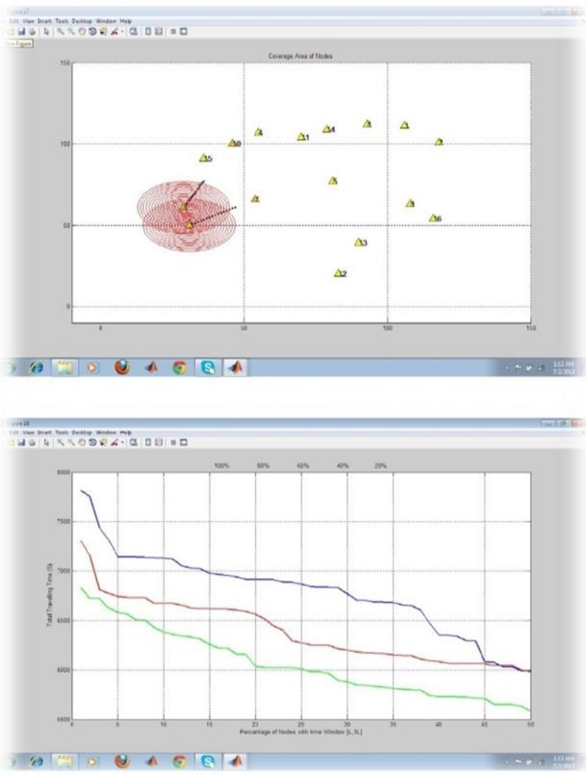

Figure 5: Coverage area of nodes & Percentage of nodes with time window

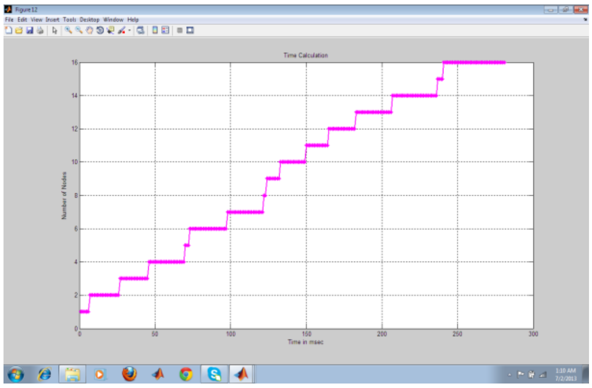

Figure 6: Time calculation of nodes

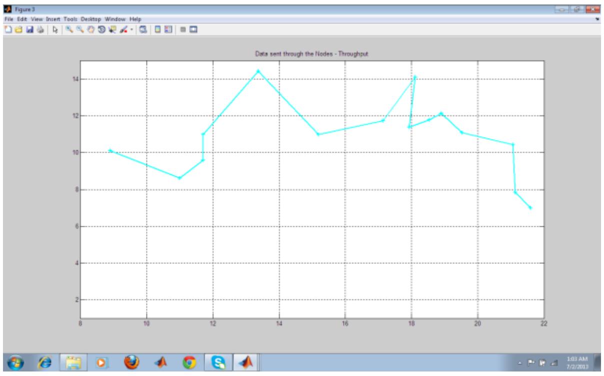

Figure 7: Data sent through the nodes-Throughput

Figure 8: Shortest path & Energy efficiency

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V. CONCLUSION

Wireless Sensor Networks (WSNs), composed of low cost, low-power, multifunctional sensor nodes. Applications of such WSN are medical treatment, environmental monitoring, outer-space exploration, emergency response, etc. senor nodes distributed over the field may act as information SOURCES. There is typically one or more SINK nodes for whom the measured data are destined to, which is located within or outside the sensing field.

In order to improve energy efficiency, another efficient way is to maximize throughput without consuming much more power of nodes. MIMO (multiple- input and multiple-output), which is a multiple-antenna technique, is regarded as one of the most promising solutions for improving spectrum efficiency and increasing capacity of wireless systems.

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