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Energy Conserved Fault Tolerance Relay Nodes in Wireless Network

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Abstract: The rapid development of wireless communications has permitted to improve low-cost, low-energy sensor nodes each accomplished of sensing, processing and communicating with neighboring nodes by means of wireless links. A Dual Tired Network Model are planned to be proposed for relay placement problem. Energy-alert and fault tolerance are two important design goals of large scale wireless sensor network. Dual Tired Network Model formulate a constrained multi-inconsistent linear programming to determine the location of the sensor nodes and data transmission pattern. Initial tier, a linear network finds optimal placement strategies algebraically using Consistent Assignment (CA) scheme. Through algebraic results, the optimal node placement strategies provide a significant benefit to minimize the energy alert total cost. In Dual Tired Network Model, second tier develops a Level Self-sufficient (LS) scheme to create a solution for fault tolerance mechanism. It also analysis the fake information sources that acted as storage nodes during the failure of links to minimize the delay time. The two objectives studied in the study are to minimize the energy consumption total cost and to develop fault tolerant mechanism. A finite number of sensor or aggregation nodes in a region with certain coverage requirement are provided to perform the experimental evaluation. Various statistical parameters computed are compared with the existing Mobile Multi-hop Relay (MMR) networks to obtain better results with 8.166% minimized energy consumption in terms of cost, effective fault tolerant and minimal delay occurrence during network re-entry.

Key words: Wireless network, Two-Tier Network Model, energy alert, fault tolerance, mobile multi-hop relay network, level self-sufficient scheme, network re-entry delay

INTRODUCTION

A wireless sensor network is collection of sensor nodes, i.e., hundreds or thousands of nodes which use wireless links to execute distributed sensing tasks. Each sensor node includes a sensing module, a computing component, memory and a wireless communication module with an extremely incomplete communication range. Wireless sensor network has received intensive research attentions due to its enormous application possible in battlefield surveillance, environmental monitoring, biomedical observation and other fields. The basic requirements for designing resourceful wireless sensor networks are fault tolerance and energy efficiency.

A sensor network comprising of a number of sensor nodes is classically required to cover a huge geographic area. New sensor nodes are additional to the network and existing sensor nodes developed effectively with the additional nodes at any time. The relay technologies review (Kumar and Nagarajan, 2013) and a technical issue in the physical and MAC layer of IEEE 802.16 is justified. It just forwards the data from frame structure, link adaptation, modulation and effective coding but the relay placement problem occurs. The failure duration notice and simultaneous transmissions might direct to significant network congestion. Therefore, survivability of sensor networks is a risky goal.

Moreover, energy is one of the major resource relay placement problem in wireless sensor networks. Relay nodes are usually powered by battery and merely last for a quite short period of time if operated at high broadcasting power levels. As a consequence, energy efficient design with fault tolerance is desirable for prolonging network lifetime.

In this study, it presents a dual tired network model. Initial tier, formulate a constrained multi-inconsistent linear programming problem to determine both the position of the nodes and the data transmission pattern. It considers two objectives namely minimize the energy alert total cost and fault tolerance on relay nodes.

Consistent Assignment (CA) scheme is a two optimal placement strategy together with performance bounds

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and linear networks. Traffic monitoring and limit line control are some applications of linear networks. Algebraic results are also evaluated after exploring and understanding the fundamentals of a linear network and extend the results to a more sophisticated planar network.

Second tier develops a Level Self-sufficient (LS) scheme to create a solution for fault tolerance mechanism. LS scheme also avoids the loss of information upon wireless link failures while being independent from protocols that are embedded in the communication stack. It holds a sensor storing monitoring reports where no next hop is available to reach the relay station.

This information is either own ones or those being relayed from other standalone devices. The storing relay nodes in wireless sensor node act as fake data sources once a path re-opens in the direction of a relay station. This large scale and regularly changing network provides Scalable algorithm for fault tolerance. The features of algorithm reduce the energy, ecological circumstances with fault tolerance and removal of malicious attacks result in minimal delay in a wireless sensor network.

Literature review: The design of wireless sensor networks depends on the application requirements. Wang *et al*. (2011a) develop an optimal power control methods to balance the tradeoff between energy efficiency and fairness for wireless cooperative networks where several relays assist the communication with faults. It does not adapt to animatedly learn the statistics of the wireless channels on-the-fly approach power control policy. Localized, self organizing, robust and energy efficient data aggregation tree approaches for sensor networks by Tan *et al*. (2010) efficiently computed using only distance information of one-hop neighbors.

A novel relay deployment framework that utilizes mobility prediction and works in tandem with the underlying MANET routing protocol to optimally define the movement of the relay nodes by Venkateswaran *et al*. (2009). De Rango *et al*. (2012) tries to account for link stability and drain rate energy consumption bit fails in measuring the future energy expenditure but its estimation depends only on node distances, residual power, hop count and node mobility.

Lin and van der Schaar (2011) enables the nodes to separately determine their routing and transmission power to maximize the network utility in a dynamic environment. Reinforcement-learning find the optimized policy when the dynamics are unidentified to relay nodes. Xu and Wang (2011) investigates the velocity limit of information propagation in large-scale multihop wireless networks which provides primary considerate of the fastest information transportation and deliver data to wireless network.

Jeong *et al*. (2012) tailored for the multihop data delivery from infrastructure nodes fails in providing user-required performance with the minimum deployment cost and also questions how to fully utilize carriers for the more efficient data forwarding in networks. Jiang *et al*. (2011) investigate capacity scaling laws for MIMO ad hoc networks to find the achievable throughput of each node as the number of nodes in the network increases but MIMO consumed more memory capacity.

Distributed adaptive opportunistic routing scheme for multi-hop wireless ad hoc networks is developed by Bhorkar *et al*. (2009) fails in developing Adaptive Opportunistic Fast Converging algorithms which optimize the regret as a performance measure of attention. Spyropoulos *et al*. (2008) holds difficult problem of multiple copies being routed in parallel given utility field to see if significant hypothetical solutions could be drawn. Gupta *et al*. (2010) formulated the problem as an Integer Linear Program (ILP) that does joint admittance control and scheduling of flows while enjoyable its rate and latency requirements.

Iyer *et al*. (2011) compute a Probably Approximately Correct (PAC) normalized histogram of comments with a revive rate. The performance of a distributed computation algorithm on the random geometric graph depends only on the scheduling constraints and the statistical properties of the graph. Park *et al*. (2011) is designed for WSNs where nodes attached to plants must transmit information via multihop routing to a sink node. The design approach relies on an inhibited optimization problem, whereby fails in achieving the objective function.

Geographic Transmission with Optimized Relaying (GATOR) provides a arithmetical design for relay selection in a time slotted geographic communication scheme. Path-loss exponent two, the relay selection scheme simplifies to depend on circular regions around the destination (Choi *et al*., 2012). El-Moukaddem *et al*. (2013) necessitate compound motion planning of mobile nodes, so it implemented only on a number of low-cost mobile sensor platforms.

O(ln n) algorithm performs badly and do not occur in the square grid with random SNs deployment (Yang *et al*., 2012). The 2-connected double-cover problem where each sensor node is enclosed by two base stations or relay nodes and the relay nodes form a 2-connected network with the base station. Zhi *et al*. (2009) fails in developing analytical models to determine the optimal number of nodes or the optimal energy harvesting rate to deploy under different scenarios.

Sharma *et al*. (2011) assign the available relay nodes to diverse source-destination pairs so as to maximize the minimum data rate among all pairs but fails in tolerating the faults. Wang *et al*. (2011a, b) choose randomly the Hybrid Extended Network (HEN) and Hybrid Dense Network (HDN) multicast strategies. The multihop scheme with BS-supported which further consists of two types of strategies called connectivity policy and percolation policy correspondingly yet faults, occurs in higher rate.

Multihop data delivery from infrastructure nodes fails in providing user-required performance with the minimum deployment cost. A Dual Tired Network Model are planned to be proposed for relay placement problem. A finite number of sensor or aggregation nodes in a region with certain coverage requirement are provided with Consistent Assignment (CA) scheme and Level Self-sufficient (LS) scheme.

MATERIALS AND METHODS

Energy alert based fault tolerance relay nodes in wireless sensor network: Consider a sensor network formed by a set of wireless sensor nodes which are consistently scattered in a rectangular region. All sensor nodes in wireless network have the same communication range 'q' in Dual Tired Network Model. The wireless sensor network consists of source node, relay nodes and destination nodes. The relay nodes are the intermittent nodes from the source to destination. The network model is dual tiered, comprising of Consistent Assignment (CA) scheme for the energy alert and the Level Self-sufficient (LS) scheme for the fault tolerance in wireless sensor network.

Every relay nodes in-between the source and destination node has a communication range, 'Q' in wireless sensor network. Normally, Q much larger than q is consistent in wireless sensor network with the present communication ranges of sensor nodes. A relay node communicates with all other sensor node within a distance 'q', the communication range of the sensor nodes are uniformly distributed for effective energy balancing. Architecture diagram of the Dual Tired Network Model is shown in Fig. 1.

Dual Tired Network Model as shown in Fig. 1 solves the problem of energy consumption, fault occurrences and delay. To achieve the assignment of data gathering, an intuitive objective places the fewest number of relay nodes in-between the node forwarding from source to destination.

Since, gathered data are transmitted to the relay node which are far away from the data sources (i.e., source node), also require more energy to communicate with each other through a multi-hop path. A set of relay nodes are connected with one other and any pair of them communicates with each other through a multi-hop path of relay nodes.

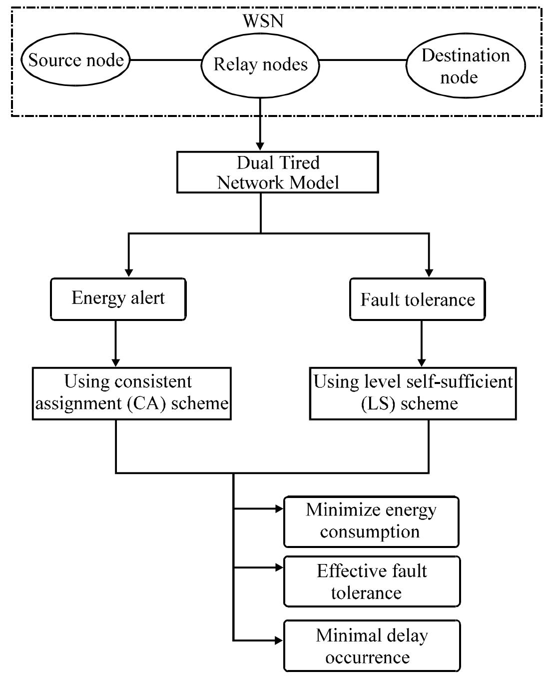

Fig. 1: Architecture Diagram of Dual Tired Network Model

Definition for more energy consumption problem: The solution to the energy consumption problem is provided through CA scheme. CA is communication associated energy usually an important component for the total energy calculation in a wireless sensor network. CA scheme mostly focus on the distance reliant and communication associated energy which provides perfect media access control. It is reasonable that the energy consumption to transmit an information element is directly proportional to the total energy consumption by a constant number.

It considers a linear sensor network consists of a set of sensor nodes placed along an extended and constricted area. The linear network covers the area of length 'L'. Each sensor node collects the data within its sensing variety; transmit information through the relay node for additional processing. Hence, for a source node to transmit a stream of information at rate 'D' to a destination node, the corresponding transmission energy 'E' is modeled as:

$$E = D \times r^{d} \quad (1)$$

where, $2 \leq d \leq 4$ is the path loss exponent, depending on network models. Perceptibly, communication over a long connection is rigorously discipline because energy consumption over a long connection is much superior than the total energy consumption over several short connections, i.e.:

$$(r_1+r_2+...+r_n)^d >> r_1^d+r_2^d+...+r_n^d \quad (2)$$

The algebraic results are provided for ‘n’ in the relay node. Each sensor node in wireless network has a definite quantity of initial energy E_0 and a sensing range ‘R’. Let r_i be the distance between relay node ‘i’ and (i+1), i = 1, ..., n-1 and r_0 be the area covered by node 1. A common scenario on each sensor node in CA scheme wireless network periodically collects constant bit rate information. Thus, it is reasonable that the amount of information generated in a unit area per unit time is a constant, namely the data density denoted by ‘f’. The node ‘i’ collects all the data between relay nodes i-1 and i. $r_i \leq R$ for all ‘i’ which guarantees the coverage.

A usually form for organizing sensor networks in CA scheme is the consistent placement of sensor nodes with equal distance in between. Such a deployment is usually the easiest and the performance of CA scheme is modeled as follow:

$$E_i = i\ L/n\ (L/n)^d f \quad (3)$$

$$T = \min\left[E_0/E_i\right] \quad i = 1, 2,..., n-1 \quad (4)$$

Where:

- E_i = Energy utilization on all the collected information of the ith relay node
- L = Length of the linear sensor network area in WSN
- E_0 = Initial energy allocated to each relay node on multi-hop path
- f = The information density
- L/n = The sensing area of each node thus the total traffic load node carries is i (L/n)

The total amount of the information from the entire linear sensor network area is aggregated to the relay node. The energy utilization is the phase of time from the network initialization to a point when one of the nodes runs out of energy without any other node cover the same sensing area in WSN. For the consistent placement, nodes closer to the sink (i.e., AP nodes) carry more relay loads, consumes lesser energy in Dual Tier Network Model.

Alternatively, data aggregation is another possible solution for energy saving in wireless sensor network. However, the tradeoff between information accuracy with fault tolerance and energy consumption are taken into account while designing an Efficient Data Aggregation Model. It finally minimizes the energy consumption which measured in terms of cost.

Definition for fault occurrence problem: Level Self-sufficient (LS) scheme is developed to provide a solution for fault tolerance mechanism. LS scheme consists of monitoring reports whenever every multi-hop path relay to the sink nodes. The accumulated information packets in LS scheme sensor nodes act as fake information sources once the next hops get obtainable data. The accumulated packets are delivered to the sink nodes in order to achieve reliable data transmission without emerging from an explicit fault tolerance mechanism.

LS scheme starts its operations whenever next hop un-reachability is detected and requires a valid next hop to the sink station existing from any sensor node in WSN. This information is available at the medium access control layer. Once a pro-active sensor detects then its next hop is no longer available and initiates the storage of all monitoring reports that it receives.

It behaves as a pro-active sensor node until it reaches a threshold set in accordance to its maximum storage capacity in WSN. Indeed, due to their limited resources, each pro-active sensor stores a certain number of messages. Consequently, pro-active sensor in LS scheme detects the failure and store messages for a short period of time only, depending on its resources and the arrival frequency of monitoring reports in WSN. Evidently, considering Fig. 2, the amount of memory space dedicated to fault-tolerance deal with potentially long periods of failure.

These messages are indeed considered as standard monitoring reports as shown in Fig. 2. The pro-active sensor, noted as ‘PS’ and selection process is triggered among the reactive sensors situated in its locality. Once a reactive sensor is selected, PS starts to forward new monitoring reports to reactive sensor node which starts to store messages instantly. In order to select a reactive sensor in LS scheme, PS broadcasts a storage request. Upon reception, reactive sensor accepting it sends a positive response to PS which gets informed about the current status of node (i.e., energy and storage capacity). The sender of the first reply received at PS is selected for storage assistance.

Any reactive sensor sends a message back to PS in order to stop the current storage process thus prompting

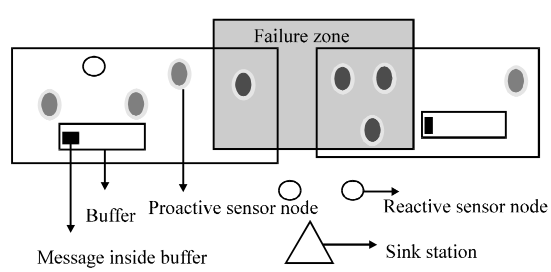

Fig. 2: LS scheme diagrammatic representation

a new storage request transmission from PS. The storage process is stateless as no information obtained. The reactive sensor nodes have stored any given number of messages on pro-active sensors. It also allows multiple selections of a given reactive device by several pro-active sensors. Once no more neighboring device is responding to storage requests (i.e., either due to distance limits), PS fakes its failure by not acknowledging messages on relay nodes. As a result, all pro-active sensors that were relying on PS as a next hop also trigger LS scheme for efficient way of performing fault tolerant mechanism.

Algorithmic flow of Dual-Tired Network Model:

Input: Set of sensor nodes includes Source, Relay and Destination nodes with different locations. E_0: initial energy allocated to each relay node on multi-hop path

Output: Fault tolerance with minimal energy utilization in wireless network including sensor nodes and relay nodes.

Step 1: Linear network covers the area of length 'L'

//**Consistent assignment scheme:**

Step 2: Transmit a stream of information at rate 'D' to a destination node

Step 3: Corresponding transmission energy 'E' measured (Eq. 1)

Step 4: Minimal energy in terms of cost measured with $\sum_{i=1}^{n} E_i (C_0 P_0)/E_0$ formulation

//**Level self-sufficient scheme:**

Step 5: Monitoring reports relay to destination nodes through sink station

Step 6: Pro-active sensor nodes, noted as 'PS', selection process is triggered

Step 7: Reactive sensor nodes is selected, PS starts forward new monitoring reports

Step 8: Transmission of stream information between pro-active and reactive sensors is seen as an additional hop toward the sink station with effective fault tolerance

The above Dual Tired Network Model algorithm describes about the consistent assignment scheme and level self-sufficient scheme. CA induces transmission of messages to destination node with additional hop toward the sink station with minimal energy alert. Similarly, the selection process imposes at least one storage request to be sent by a pro-active sensor nodes and at most one response per neighboring reactive device.

Experimental evaluation: Energy alert based fault tolerance on relay nodes in a wireless sensor network use ns-2 network simulator. In simulation, set up 'n' nodes consistently at randomly surrounded by 900×900 squares with n unpredictable among 100 and 900 formative the sensor node group patterns. In particular, to accurately estimate the production of the structure each node progress to a randomly selected position with a randomly selected velocity amongst a predefined minimum and maximum speed.

In the Random Way Point (RWM) Model, each node shift to an erratically chosen location with a randomly selected speed between a predefined smallest amount and highest speed. It assumes the normal unit disc bidirectional communication replica and adjust the message range so that each node will roughly have 35 neighbors on average. An RWM standard holds the total number of mail sent or received per node. It calculates the communication requirements and measure resiliency by counting the number of times protocol run in order to detect a single node replication.

The affecting wireless sensor networks continue there for a predefined pause time. After the pause time, it then randomly chooses and moves to another location. This random progression is constant during the simulation period. All simulations were performed for 750 simulation seconds, fixed a pause time of 40 simulation seconds and a minimum moving speed of 1.5 m sec^{-1} of each node.

RESULTS AND DISCUSSION

The performance of the energy alert based fault tolerance on relay nodes in a wireless sensor network measured energy consumption in terms of cost, fault tolerant and delay occurrence during network re-entry.

Energy consumption in terms of cost is defined as the rate it taken to transfer data from source to destination through the relay nodes. It is measured in terms of joules (J). Let C_0 is the cost of replacing either a sensor node or an aggregation node, P_0 the operating period of time required by a specific application. The total cost of replacing in the period of time P_0 is proportional to the total times the relay nodes are replaced from source to destination node. Such a problem could be identified as:

$$\text{Cost function} = \frac{\sum_{i=1}^{n} C_0 P_0}{P_i} = \frac{\sum_{i=1}^{n} C_0 P_0}{E_0/E_i} = \frac{\sum_{i=1}^{n} E_i (C_0 P_0)}{E_0}$$

Where:

E_i = Energy utilized per element time for sensor node

E_0 = Initial energy of each relay node, on multi-hop path

$(C_0P_0)/E_0$ = A constant to minimize the total energy consumption in Dual Tier Network Model

Fault tolerance rate is defined as the lowest level of ability to continue operation in the event of a failure in the wireless sensor network. The fault is controlled after recognition of the information loss from the source to the relay nodes using the wireless sensor network:

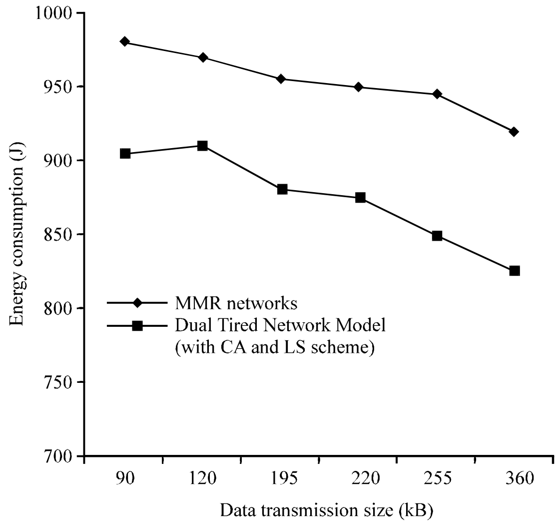

Fig. 3: Data transmission size vs. energy consumption

$$\text{Fault tolerance rate} = \frac{\text{No. of data sent - No. of received data}}{\text{Group of data in session for transmitting}}$$

The delay of a wireless sensor network identifies how long it takes time to receive a bit of data from one source node to relay node and from the relay nodes to destination. It is typically considered in multiples or fractions of milliseconds (msec).

Figure 3 describes the energy consumption based on the data transmission size. The data transmission rate is measured in terms of kilo Bytes (kB). min E_0/E_i collected information of the ith relay node and reduces the energy in terms of cost using the CA scheme. Dual Tired Network Model with CA scheme is 5-10% decreased consumption of energy in terms of cost when compared with the Mobile Multi-hop Relay (MMR) networks.

Figure 4 describes the fault tolerance rate based on the source to relay node data rate. Fault tolerance rate is measured in terms of hertz (Hz) and data rate is measured in terms of mega Bytes (MB). Dual Tired Network Model with LS scheme is 2-5% higher rate in fault tolerance when compared with the Mobile Multi-hop Relay (MMR) networks (Kumar and Nagarajan, 2013). Selection process is triggered among the reactive sensors in LS scheme for effective fault tolerance rate.

The delay rate during network re-entry is measured based on the samples performed in wireless sensor network. Depending on its resources and the arrival frequency of monitoring reports in WSN, delay rate during network re-entry is reduces drastically. As the sample time increases, the delay rate during network re-entry in terms of milliseconds is reduced. The delay rate is 5-8% lesser when compared to the Mobile Multi-hop Relay (MMR) networks (Fig. 5).

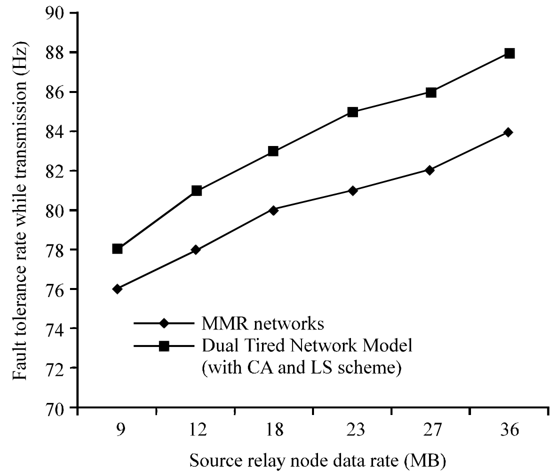

Fig. 4: Data rate vs. fault tolerance rate while transmission

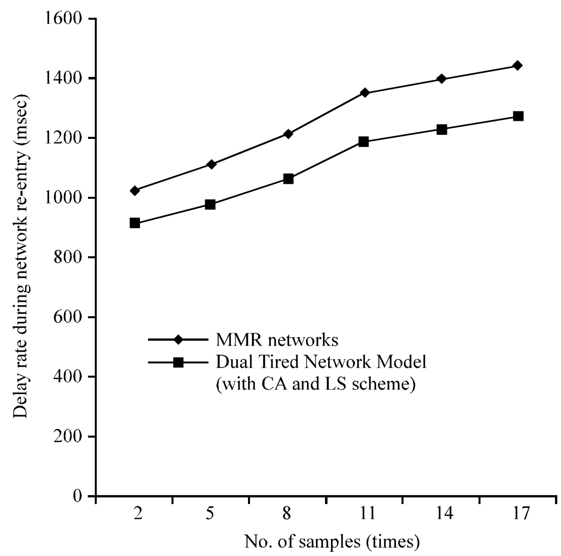

Fig. 5: No. of samples vs. delay rate

Finally, energy consumption while transmitting data and fault tolerance effectively on wireless sensor network relay nodes achieved separately and focused exclusively on delay measure during network re-entry. A Stateless Fault Tolerance Method in wireless sensor network thus makes certain low message complexity and low energy consumption in terms of cost.

CONCLUSION

Energy-alert and fault tolerance are designed together in large scale wireless sensor network. Dual Tired Network Model formulate a linear programming to determine the data transmission pattern. A linear network finds optimal placement strategies algebraically using Consistent Assignment (CA) scheme for providing a significant benefit to minimize the energy alert total cost. Level Self-sufficient (LS) scheme analysis the fake information sources that acted as storage nodes during the failure of links. Dual Tired Network Model algorithm allows the monitoring reports to be stored effectively with fault tolerance. A finite number of sensor or aggregation nodes in a region with certain coverage requirement are provided to perform the experimental evaluation in ns-2 simulator. The parameters worked out are compared with the existing Mobile Multi-hop Relay (MMR) networks to obtain better results with 8.166% minimized energy consumption in terms of cost, effective fault tolerant and minimal delay occurrence during network re-entry. Also, plan to investigate optimizations with topology control in the future research.

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