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Performance Analysis of Cluster Based Dual Tired Network Model with INTK Security Scheme in a Wireless Sensor Network

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Abstract**—**A dual tiered network model is designed to overcome the problem of energy alert and fault tolerance. This model minimizes the delay time and overcome failure of links. Performance analysis of the dual tiered network model is studied in this paper where the CA and LS schemes are compared with DEO optimal. We then evaluate the Integrated Network Topological Control and Key Management (INTK) Schemes, which was proposed to add security features of the wireless sensor networks. Clustering efficiency, level of protections, the time complexity is some of the parameters of INTK scheme that were analyzed. We then evaluate the Cluster based Energy Competent n-coverage scheme (CEC n-coverage scheme) to ensure area coverage for wireless sensor networks.

Keywords**—**CEC n-coverage scheme, Clustering efficiency, Dual tired network, Wireless sensor networks.

I. Introduction

ENERGY-ALERT and Fault tolerance are important challenges in large scale wireless sensor networks [11]-[23] with low cost, self-organizing behavior, sensing ability and large application extent. Dual tired network model determined the location of sensor and data transmission pattern by formulating a constrained multi-inconsistent linear programming to determine the location of the sensor nodes and the data transmission pattern. Consistent Assignment (CA) scheme in first tier addressed optimal placement strategies algebraically which minimized the energy alert total cost of the network. On the other hand, second tier developed a Level Self sufficient (LS) scheme using which the issues in fault tolerance is solved.

One of the most challenging topics in relay network is security. Incorporated Network Topological control and Key management (INTK) scheme on the relay network provided effective routing and security solution. The privacy of the network is improved by key management and simultaneously, the relay nodes are validated for security measures. INTK Scheme facilitates better security and routing, active protection, robust re-keying, low time complexity and the multiple intensity of encrypt features in relay networks.

In addition to security, the coverage area of the network [1] is handled in Cluster based Energy Competent n- coverage scheme (CEC n-coverage scheme) by monitoring the nodes with better energy consumption. CEC n-coverage used sensor scheduling scheme based on the n-density, which evaluated the state of all deployed sensors to be active or sleep state depending on the remaining energy. CEC n-coverage scheme triggered a minimum number of sensors guaranteeing coverage area and stopped some redundant sensors consuming energy and extend the network lifetime.

A range of numerical parameter is computed using ns2 simulator on Dual tired network model with CA and LS scheme [2], Incorporated Network Topological control and Key management (INTK) scheme [3] and CEC n-coverage scheme [4]. Simulation results showed better performance of the Dual tired network model with CA and LS scheme, INTK and CEC n-coverage scheme in wireless sensor network in terms of the energy consumption [5]-[7], reduced fault tolerant, level of protection, clustering energy dissipation, coverage ratio and network lifetime compared to Distributed Energy Optimization (DEO) [8], Secure Data Aggregation (SDA) [9] and Optimal Routing and Data Aggregation (ORDA) [10] method.

II. Performance Analysis of Energy Alert Based Fault Tolerance Relay Nodes in WSN

The principle objective of dual tier network model with CA and LS scheme is to minimize the total energy consumption cost and to reduce the fault occurrence. A definite number of sensors or aggregation nodes in an area with certain coverage requirement are provided to perform the experimental evaluation. An energy alert based fault tolerance on relay nodes in a wireless sensor network use the NS-2 network simulator. All simulations were performed for 750 simulation seconds for a fixed pause time of 40 simulation seconds and a minimum moving speed of 1.5 m/s of each node.

The performance of the Energy alert based fault tolerance on relay nodes in a wireless sensor network is decided based on energy consumption and fault tolerance. Various statistical parameters are computed and compared with the existing Distributed Energy Optimization (DEO) [4] to obtain better results in terms of minimizing energy efficiency, lower communication cost and minimal delay occurrence during network re-entry.

A. Energy Efficiency

The energy consumption rate for sensors in a wireless sensor network differs widely based on the network tier the

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sensors are used for communication. Transmitting and receiving data, executing applications, computing power and even residing in reserve mode consumes energy. Energy consumption of each sensor straightforwardly changes the network operational lifetime. The continuous energy consumption is the smallest amount of energy required to maintain the network during its lifetime without data loss, battery leakage and sensor sleeping energy.

Table I illustrates the energy efficiency during data transmission. The data transmission rate is measured in terms of KiloBytes (KB). Based on Table I , Fig. 1 is depicted.

TABLE I
DATA TRANSMISSION SIZE VS ENERGY EFFICIENCY

Data Transmission Size (KB)	Distributed Energy Optimization (DEO)	Dual Tired Network Model (With CA And LS Scheme)
50	900	785
100	910	805
150	925	825
200	940	840
250	955	855
300	1000	862
350	1025	880

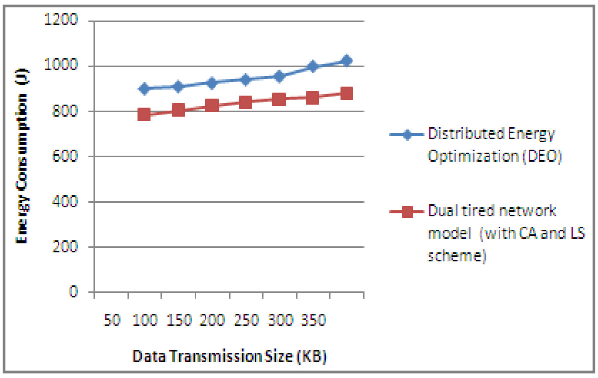

Fig. 1 Data Transmission Size vs. Energy Consumption

Fig. 1 describes the energy consumption based on the data transmission size. Dual tired network model with CA scheme provides a high energy consumption of 10–15% compared to the Distributed Energy Optimization (DEO). As sensor networks in CA Scheme reliably placed the sensor nodes with equal distance in between, the loss of energy is highly reduced in the Dual tired network model with CA scheme. While Distributed Energy Optimization (DEO) faces the dynamic awakening problem with only the group of sensor nodes, which are located in the vicinity of the target will be awakened by increasing the energy consumption and reducing the energy efficiency.

B. Delay Occurrences

Delay occurrence is defined as the difference in the time delay of transmitting and receiving the packets. The nodes in a network with a synchronized clock are able to identify the time delay between the sender and receiver's message. Recognizing the delay from one node to another is simple. The sender places a timestamp when sending a packet and the receiver places a timestamp when receiving the packet. The difference of the two timestamps is the single instance of the delay.

Table II illustrates the tabulation for delay occurrence with respect to the number of packets transmitted to the receiver. Based on Table II, Fig. 2 is depicted.

TABLE II
NUMBER OF PACKET VS DELAY OCCURRENCE

No. Of Packet	Distributed Energy Optimization (DEO)	Dual Tired Network Model (With CA And LS Scheme)
10	25.5	10.2
20	32.5	15.9
30	43.7	20.3
40	60	22.4
50	62.2	25.6
60	65.25	29.2
70	74.5	34.8

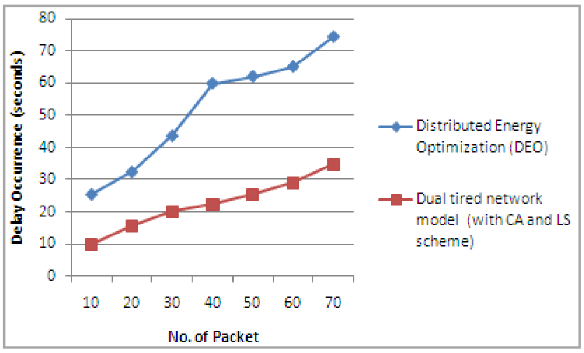

Fig. 2 No. of Packet vs. Delay Occurrence

The delay occurrence is measured based on the samples performed in wireless sensor network. The delay during transmission in Dual tired network model with CA and LS scheme is 51–62% lesser compared to the Distributed Energy Optimization (DEO). As soon as the reactive sensor is selected, PS starts to forward new monitoring reports to reactive sensor node which store messages instantly minimizing the delay occurrence in the Dual tired network model using CA and LS scheme. In addition to the LS scheme analyzed the fake information sources which acted as storage nodes during the failure of links minimized the delay time. The optimization of energy in a distributed manner during the selection of each sensor node in Distributed Energy Optimization (DEO) results in daily occurrence.

C. Communication Cost

Communication cost is defined as the cost required during the transmission of data to the destination through relay nodes. Certain algorithm reduces communication costs by removing or minimizing the repeated sensor information of certain nodes and also discards the data to be forwarded which is inappropriate. Nodes measured averages and directionality based on the evaluation of data forwarding. The communication cost of energy consumption is measured in MJ. Table III describes the performance of both DEO and

Dual tired network model with CA and LS scheme in terms of communication cost.

Table III illustrates the communication cost of energy consumption. Both existing MMR networks and proposed Dual tired network model with CA and LS scheme is measured in term of communication cost. Based on Table III, Fig. 3 is depicted.

TABLE III
SOURCE TO RELAY NODE DATA RATE VS COMMUNICATION COST

Source To Relay Node Data Rate (KB)	Distributed Energy Optimization (DEO)	Dual Tired Network Model (With CA And LS Scheme)
10	1.05	0.90
20	1.6	1.19
30	1.95	1.68
40	2.45	2.17
50	2.85	2.54
60	3.25	2.86
70	3.40	3.04

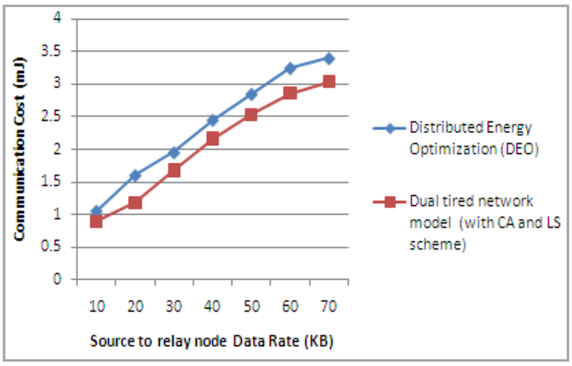

Fig. 3 Source to relay node Data Rate vs. Communication Cost

Fig. 3 describes the communication cost of energy consumption during the data transmission. Dual tired network model with CA and LS scheme provides a lower communication cost of about 12-25% compared to DEO in wireless sensor networks. As a relay node communicates with all the other sensor nodes within a distance, the communication range of the sensor nodes is uniformly distributed for effective energy balancing and reduced communication cost in the dual tired network model with CA and LS scheme.

Finally, energy is consumed during data transmission and fault occurrence is reduced effectively on wireless sensor network relay nodes. The data transmitted is received certainly without loss and as a result delay occurrence is avoided. A stateless fault tolerance method in wireless sensor network makes certain low message complexity and low energy consumption in terms of communication cost.

III. ANALYSIS OF INTK SCHEME

Security scheme is designed with the consideration of multi cluster based topology control through a multiple intensity keying. Integrated Network Topological Control and Key Management (INTK) Scheme provides better privacy to the network through key management. Multi cluster based topology control through an intensity keying consumes lesser communication, energy due to its multi cluster key executive. INTK is highly realistic as it is intended to incorporate the routing layer and security protocol without sacrificing energy.

A variety of numerical parameters are computed using the NS-2 simulator on SDA processes in wireless sensor networks [23] and proposed INTK Scheme. Relay network provides the effective routing and security solution. The behavior of INTK scheme is forecasted in terms of metrics like level of protection, clustering efficiency with multi-cluster key and minimum time complexity.

A. Clustering Efficiency

Clustering operations are mainly effective in increasing the network scalability and reducing data latency which are highly utilized. A multi-cluster includes a group of neighboring nodes where one of the group nodes is selected as Cluster Head (CH).

The multi-cluster use parameters such as sensor energy level, mobility, position to form multiple clusters and determine CH. The multi-clustering process generates multi-clustering key which further improves the security of the nodes. In addition to multi-clustering key, the private key and structure key make the task of deciphering more complex for different portions of the message.

Table IV describes the tabulation for clustering efficiency in decrypting the message received. The process of decrypting the message in Integrated Network Topological Control and Key Management (INTK) Scheme is difficult for an intruder with the establishment of the private key, multi-cluster key and structures key. But the NTA processes for non transparent mode relay network does not concentrate on clustering. Based on Table IV, Fig. 4 is depicted.

TABLE IV
NUMBER OF DECRYPT MESSAGES VS CLUSTERING EFFICIENCY

No. Of Decrypt Message	SDA Process	INTK Scheme
5	75	89
10	72	80
15	55	65
20	50	55
25	40	47
30	27	30
35	22	26

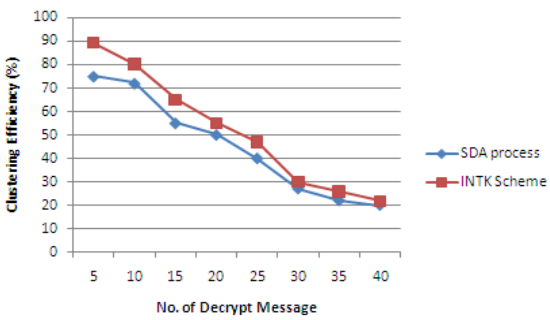

Fig. 4 No. of Decrypt Message vs. Clustering Efficiency

Fig. 4 describes the clustering efficiency while decrypting a message. The data portion of all messages within is encrypted with different multi-cluster keys. The INTK scheme energy used to communicate is 10-18% lesser when compared with the SDA process. As a relay node in communication holds information of network topology control and realized network functionality, the decrypting information portions need the exact key in INTK scheme resulting in better clustering efficiency. In addition, positioning the new node and forming the head for multi-cluster in INK scheme replaced the failed relay nodes enhancing the clustering efficiency. But the process involved in SDA collapses the nodes as the node concentrates more on data confidentiality and integrity without the cluster formation minimizing the clustering efficiency.

B. Level of Protection

The level of protection is defined as the amount of security provided for the execution of an obligation, i.e., the information encrypted and decrypted using INTK scheme in wireless relay network. The accessibility of data to third parties causes numerous disasters in many security related applications. The performance of SDA process and INTK scheme is examined regarding the security level provided to the nodes. Level of protection is measured in terms of percentage (%).

Table V shows the level of protection in terms of percentage for INTK scheme and NTA process. The level of protection provided in Integrated Network Topological Control and Key Management scheme is measured against SDA processes for non transparent mode relay networks.

The protection level of SDA process in wireless sensor network and INTK scheme are examined and the output is obtained in terms of percentage (%). The multi cluster key is used for security and used to encrypt the information portions of all messages exchanged within the cluster on relay network. The encrypted message is decrypted on the other side, which will definitely improve the security of INTK scheme to 5.5% when compared with the SDA process. In the SDA process, the sensor nodes, which are in the coverage area of base stations are accepted independently without any access permission causing security threat.

TABLE V
TABULATION FOR LEVEL OF PROTECTION

Technique	Level Of Protection (%)
INTK Scheme	88.80
SDA Process	82.30

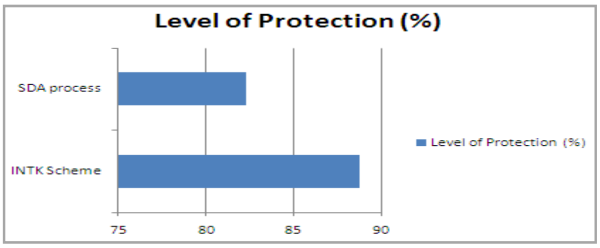

Fig. 5 Techniques vs. Level of Protection

C. Time Complexity

Time complexity is defined as the time taken to deliver the packets or data to the destination with better energy consumption, high security and fault free communication. The time complexity is also defined as the flow time from the time when the first message was forwarded to the time when the last message was received.

$$\text{Time complexity} = \text{Time (Fisrt Message Forwarded} + \text{Last Message Received)}$$

The time complexity of both SDA process in wireless sensor network and INTK scheme is forecasted to decide the individual performance. Table VI and Fig. 6 describes the ability of SDA process and INTK scheme.

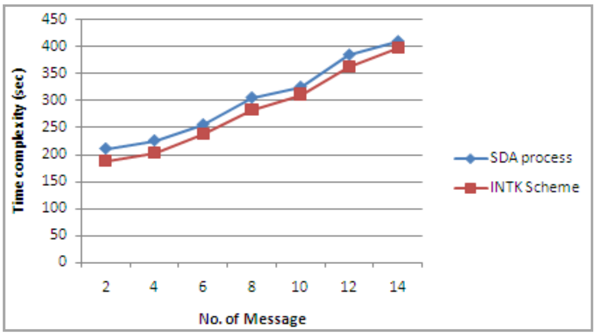

Fig. 6 No. of Messages vs. Time Complexity

Table VI describes the tabulation for time complexity measured in seconds. INTK scheme provides a minimum time complexity compared to the SDA process with a wireless sensor network. Based on Table VI, Fig 6 is depicted.

TABLE VI
NUMBER OF MESSAGES VS TIME COMPLEXITY

No. Of Message	SDA Process	INTK Scheme
2	210	188
4	225	202
6	255	238
8	305	283
10	325	311
12	385	362
14	410	397

Fig. 6 describes the time complexity based on the average nodes involved in the processing for transmitting a message. The INTK scheme takes lesser time about 3-10% compared to the SDA process in wireless sensor network. The broadcasts information, encrypted with the latest structure, key reduces time complexity in INTK. Therefore, a relay node is totally ignored by the rest of the INTK scheme if the node does not involve the latest structure key. On the other hand, an SDA process in wireless sensor network consumes more time (i.e., the waiting time during transmission) in the scanning period where the Base station allocates time intervals to other sensor nodes resulting in more time complexity.

Finally the Integrated Network Topological Control and Key Management (INTK) Scheme proved to be performing better compared to SDA processes for combined data aggregation and security in terms of clustering efficiency, level of protection and time complexity.

IV. Performance Analysis of Cluster Based Energy Efficiency and Fault Tolerance N-Coverage in WSN

Cluster based Energy Competent n- coverage scheme (CEC n-coverage scheme) finally ensured the area coverage of a monitored area with high energy consumption. CEC n-coverage scheme utilized sensor scheduling scheme based on the n-density and improved the energy efficiency. The remaining energy of each sensor is evaluated which decided the state of all the deployed sensors categorizing nodes as either active or sleep state supporting energy saving and reduction in fault occurrence. CEC n-coverage scheme triggered a minimum number of sensors guaranteeing coverage area and also redundant sensors are turned off saving energy and extending the network lifetime.

Experimental evaluations on CEC n-coverage scheme is conducted to test the coverage area ratio, clustering energy dissipation and network lifetime. CEC n-coverage facilitated the ensured full coverage of the monitored area, involving the smallest amount number of sensors. As a result, energy consumption is minimized and therefore the network lifetime is also extended. Simulation results attempts to prove the better performance of the CEC n-coverage algorithm compared to Optimal Routing and Data Aggregation (ORDA) of wireless sensor networks [4] in terms of clustering energy dissipation, coverage ratio and network lifetime.

A. Clustering Energy Dissipation

Clustering Energy dissipation is defined as the amount of energy consumed after clustering during data transmission from source sensing node to sink node in wireless sensor network. The energy dissipation derivation of transmitting and receiving data between two sensors is as follows

Energy dissipation of transmitting data

$$T_x\,(M,d) = E\ * M + C * M * d2 \text{ where d} > 1$$

Therefore, the power consumption of data transmission between two sensors is proportional to the square of their distance. Energy dissipation of receiving data:

$$R_x\,(M) = E * M$$

while *M* is the data message to be transmitted (bit), *d* is the distance between two sensors, *E* is the energy dissipation to perform data transmission in terms of J/bit, *C* is the energy dissipation clustering constant used to increase the area coverage in terms of J/(bit*m2).

Table VII describes the energy dissipation forecasted with respect to the number of data transmitted and received. Based on Table VII, Fig. 7 is depicted.

Fig. 7 describes the clustering energy dissipation based on the number of data transmitted and received. CEC n-coverage scheme utilized 20–30% lesser energy for communication compared to ORDA method. As CEC n-coverage scheme turned on only sensor nodes, which are able to generate complete area coverage and also the unnecessary nodes are turned off which in turn saved energy. Additionally, a sensor node sends the data from the origin sensor node to sink node without the loss of data causing minimal energy. The restricted utilization of sink node with the consideration of only one sink node in ORDA [4] is unable to control the unnecessary nodes causing lower energy efficiency.

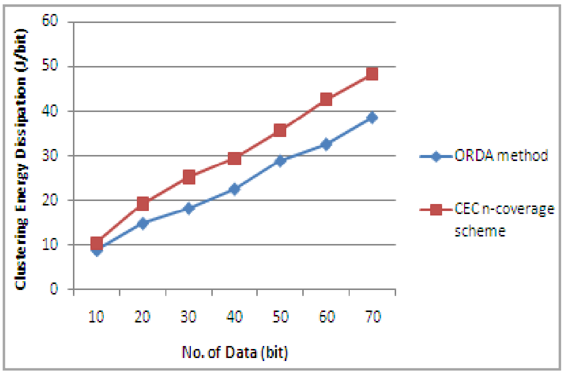

Fig. 7 No. of Data vs. Clustering Energy Dissipation

TABLE VII
NUMBER OF DATA VS CLUSTERING ENERGY DISSIPATION

No. Of Data (Bit)	ORDA Method	CEC N-Coverage Scheme
10	8.8	10.6
20	14.8	19.3
30	18.2	25.2
40	22.5	29.4
50	28.8	35.6
60	32.5	42.5
70	38.5	48.1

B. Coverage Ratio

The coverage ratio is defined as the ratio of the entire area to the covered area of the sensor. CEC n-coverage scheme schedules sensor activities to sustain the full area coverage based on the algorithm. If this coverage ratio is lower than the ratio required, CEC n-coverage enhances coverage by activating the other sensors.

$$\text{Coverage Ratio} = \frac{\text{Entire Area}}{\text{Covered Area}}$$

In addition, when the coverage ratio is less than the expected percentage than there are holes in the monitored area mentioning that points are not enclosed in the monitored area.

Table VIII describes the ratio of coverage area of wireless sensor networks on performing CEC n-coverage scheme and ORDA method. The CEC n-coverage achieves a higher percentage in the coverage ratio as the amount of sensors increase compared to the Optimal Routing and Data Aggregation (ORDA) method.

The ratio of coverage area in CEC n-coverage scheme and ORDA method are inspected in Fig 8. Better percentage difference of about 5-19% is achieved in CEC n-coverage scheme compared to the ORDA method. The CEC n-coverage scheme point checks q∈C is n-covered or not, based on the sensing range of sensors. Determination of q using n-covered ⇔ |Cover (q) | ≥ n facilitates the measure of q increasing the coverage ratio. But in the ORDA method, the BS coverage is low and medium average respectively.

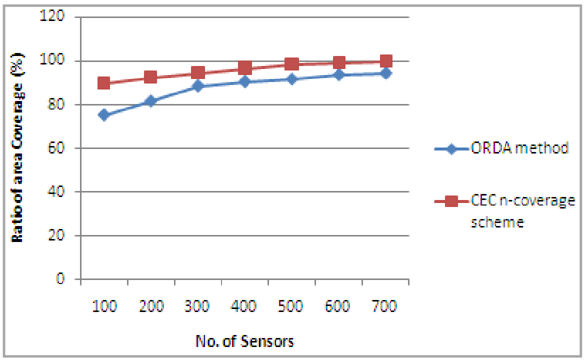

Fig. 8 No. of Sensors vs. Coverage Ratio

TABLE VIII
NUMBER OF SENSORS VS COVERAGE AREA

No. Of Sensors	ORDA Method	CEC n-Coverage Scheme
100	75.2	89.9
200	81.5	92.6
300	88.4	94.3
400	90.4	96.8
500	91.5	98.6
600	93.5	99.1
700	94.2	99.8

C. Network Life Time

The network lifetime is defined as the time period starting from network set up to the time when the stage of area coverage is lower than a certain threshold. Network lifetime turns into a major characteristic for estimating sensor networks in an application specific way. More specifically the availability of nodes, the sensor coverage area and the network connection decides network lifetime. Network lifetime was forecast at the time within which the monitored area is covered by sensor nodes based on certain determination. The network lifetime based on sensor area coverage is defined as

$$\text{Network Lifetime} = \frac{\text{Sensor Node}}{\text{Monitored Area Coverage}}$$

The condition is that the area covered by all sensors must be greater than a definite portion of the deployment area.

Table IX describes the network lifetime. The CEC n-coverage provides longer network lifetime compared to Optimal Routing and Data Aggregation (ORDA) method. Based on Table IX, Fig. 9 is depicted.

Fig. 9 describes the network lifetime based on the sensor node coverage. CEC n-coverage scheme attained 20-36% higher network lifetime compared with ORDA method. CEC n-coverage scheme turned on a minimum number of sensors that are able to ensure coverage area and turned off some redundant sensors extending the network lifetime. But the smoothing function to approximate the original max function which only approximates for achieving the optimality and as a result, fault occurrence is also high minimizing the network lifetime.

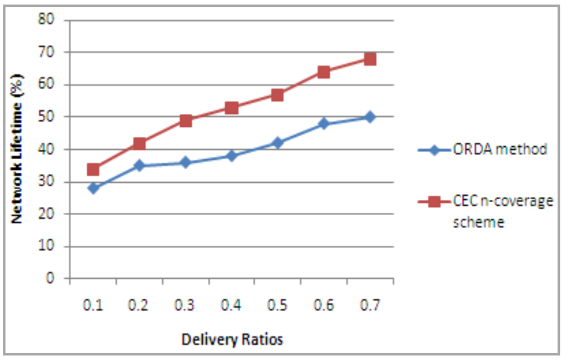

Fig. 9 Delivery Ratios vs. Network Lifetime

TABLE IX
DELIVERY RATIO VS NETWORK LIFE TIME

Delivery Ratios	Orda Method	Cec N-Coverage Scheme
0.1	28	34
0.2	35	42
0.3	36	49
0.4	38	53
0.5	42	57
0.6	48	64
0.7	50	68

Finally, cluster based energy competent n-coverage scheme guarantees the full coverage of a monitored area with better energy consumption. CEC n-coverage scheme uses an active sensor scheduling scheme based on the n-density and the remaining energy of each sensor decides the state of all the deployed sensors. Simulation results showed that CEC n-coverage scheme in wireless sensor network provides better performance in terms of clustering energy dissipation for about 20-30%, ratio of area coverage around 5-19% and the network lifetime based on sensor nodes about 20-36% compared to ORDA method.

V. CONCLUSION

Energy-alert and Fault tolerance in large scale wireless sensor network, developed an efficient Dual-tiered network model that formulated a linear programming to determine the data transmission pattern. A linear network found optimal placement strategies algebraically using Consistent Assignment (CA) scheme minimizing the energy alerts total cost. Level Self-sufficient (LS) scheme analyzed the fake information sources that acted as storage nodes reducing the failure of links. Dual-tired network model algorithm protected the monitoring reports and stored effectively using fault tolerance mechanism. Simulation results proved the better performance of the Dual-tiered network model with CA and LS scheme in terms of communication cost, energy consumption and delay occurrence.

Security scheme is designed with consideration of the multi cluster based topology control through a multiple intensity keying. Integrated Network Topological Control and Key Management (INTK) Scheme provides better privacy to the network through key management. Multi cluster based topology control through an intensity keying consumes lesser communication, energy due to its multi cluster key executive. INTK is highly realistic as it is intended to incorporate the routing layer and security protocol without sacrificing energy.

INTK scheme proved better performance in terms of metrics like level of protection, clustering efficiency with multi-cluster key and minimum time complexity.

cluster based energy competent n-coverage scheme (CEC n-coverage scheme) finally ensured the area coverage of a monitored area with high energy consumption. CEC n-coverage scheme utilized sensor scheduling scheme based on n-density and improved energy efficiency. The remaining energy of each sensor is evaluated which decided the state of all the deployed sensors categorizing nodes as either active or sleep state supporting energy saving and reduction in fault occurrence. CEC n-coverage scheme triggered a minimum number of sensors guaranteeing coverage area and also redundant sensors are turned off saving energy and extending network lifetime. Experimental evaluations on CEC n-coverage scheme proved the coverage area ratio, clustering energy dissipation and network lifetime.

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