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Energy and Trust Aware Multivariate Probit Classification for Secured Cold Storage Using WSN

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Abstract: **Wireless Sensor Network (WSN) plays a significant role in cold storage system. Few research works are designed for environmental monitoring of cold storage system using WSN. The conventional technique does not provide better performance for attaining both safety and quality of products in cold storage system. To overcome these limitations, Energy and Trust Aware Multivariate Probit Classification (ETAMPC) Model is proposed. The ETAMPC Model authenticates the sensor nodes during the data communication in cold storage system using Multivariate Probit Classification (MPC). Initially, energy and trust level of each sensor nodes in cold storage system are calculated. Based on the energy and trust level of nodes, then classification is carried out using MPC. The MPC is a generalization of probit model where it classifies the sensor node as authentic or malicious based on results of probability measurement. This assists ETAMPC Model to enhance the classification accuracy and reduce the authentication time. After completing classification process, ETAMPC Model selects authentic nodes to broadcast gather data i.e. temperature, humidity, etc to sink node without any data loss. This assists for ETAMPC Model to effectively monitor the temperature, humidity changes in cold storage. Thus, ETAMPC Model enhances both safety and quality of products in cold storage system as compared to existing works. The simulation of ETAMPC Model is carried out on factors such as classification accuracy, authentication time, and security level and energy consumption with respect to number of sensor nodes. The simulation result shows that the ETAMPC Model is able to improve the security level and reduces the energy consumption of cold storage system when compared to state-of-the-art-works.**

***Keywords* —Authentication, Classification, Cold Storage System, Energy, Sensor Node, Trust, WSN.**

I. INTRODUCTION

WSN comprises huge number of sensor nodes to perform sensing tasks within designated operation area. With limited energy resources, the nodes are capable of sensing the physical phenomena like temperature, vibrations, sounds, etc. WSN is applied in numerous applications such as agriculture, environmental monitoring and heavy industry. The sensed data are transmitted cooperatively in network by forwarding the data from one node to another node in a multiple-hop transmission. Authentication is one of the security goals during the data communication in WSN. The existing authentication techniques failed to improve the classification accuracy which affects both safety and quality of products in cold storage system. Thus, efficient monitoring and effective information management system are needed to increase security level of cold storage.

Therefore, ETAMPC Model is designed by using classification technique.

An ActiveTrust scheme was introduced in [1] for improving security in WSN. The authentication time using ActiveTrust scheme was more. In [2], Monitoring System for Frozen and Chilled Aquatic Products (MS-FCAP) was designed. Security and quality of the products was not solved effectively.

A Linear Programming (LP) Framework was introduced in [3] for obtaining security in WSN. The LP framework was not employed for diverse aspects of route diversity with lower energy consumption. A state space battery model was introduced in [4]. But, addressing the security threats was not considered.

The challenges for good network coverage, network lifetime and physical design were addressed in [5] to manage with harsh environments. It failed to secure and manage the crop storage in harsh environments. A tool for benchmarking cold-storage systems was designed in [6] for minimizing power utilization. Superconducting flywheel energy storage (SFES) system was presented in [7] to

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decrease energy. A novel technique was designed in [8] to effectively manage the stored fruit in cold storage using electronic and information technology. The energy consumption was remained unsolved.

A novel method was designed in [9] with aim of increasing the heat transfer without significantly compromising the cold storage capacity. Secured cold storage was not attained. Temperature-dependent models was presented in [10] for seed germination in aquatic systems. The security and energy of cold storage was not addressed.

In order to resolve the above said existing issues, ETAMPC Model is introduced. The main contributions of ETAMPC Model is formulated as,

- To attain higher security and maintain the quality of products in cold storage system as compared to existing works, ETAMPC Model is developed. In order to obtain secured cold storage, ETAMPC Model authenticates all sensor nodes in cold storage system with assists of classification technique.

- To increase the classification performance for node authentication as compared to state-of-the art works, Multivariate Probit Classification (MPC) is proposed in ETAMPC Model. On the contrary to existing works, MPC considers the energy utilization and trust value of sensor nodes to get higher classification accuracy.

The paper is formulated as follows: Section 2 presents the related works. In Section 3, ETAMPC Model is explained with help of architecture diagram. In Section 4, Simulation settings are described and the result discussion is presented in Section 5. Section 6 depicts the conclusion of the paper.

II. RELATED WORKS

An effect of cold chain temperature was analyzed in [11]. A novel technique was developed in [12] to ensure the quality and safety of aquatic products. The time complexity was very higher. The sensor-based method was introduced in [13] for multi-commodity refrigerated storage. Ontology-Based Cold Chain Logistics Monitoring and Decision System were presented in [14] to minimize power consumption.

An intelligent tracking system was presented in [15] for monitoring goods in the cold chain with lowest cost. A novel mechanism was intended in [16] using WSN and Sensor Cloud System to monitor cold chain logistics as part of the IoT technology. A novel system was designed in [17] to trace and monitor agricultural products' yields and distribution channel with WSN techniques.

In [18], the efficiency and margin of security in postharvest irradiation treatments using cold storage was improved. Nondestructive Analysis was presented in [19] in order to monitor quality during cold storage. The security of cold storage was remained unsolved. An optimization of energy consumption during cold storage was performed in [20] through enhancing both constructive and operating parameters. Solar-Powered Cold Storage System was introduced in [21] for horticultural crops. Secured data communication was not attained.

III. ENERGY AND TRUST AWARE MULTIVARIATE PROBIT CLASSIFICATION MODEL

A large number of sensor nodes are placed in the storage and formulated a self-organized network to observe the environmental data changes such as temperature, humidity and gas concentration, etc. The structural design of the cold storage environment monitoring using WSN is shown in below Figure 1.

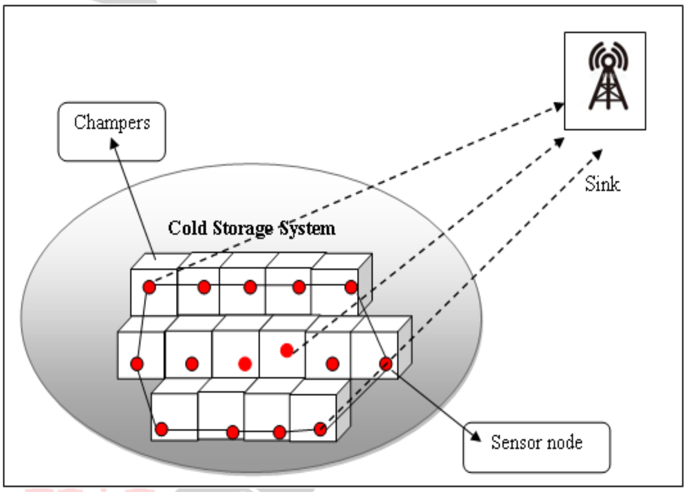

Figure 1 Cold Storage System Monitoring using WSN

Figure 1 depicts the monitoring process of cold storage system using WSN where it contain number of sensor nodes and sink node. As shown in figure 1, sensor nodes collect the data and transmit it to the sink node. WSN is emerging as a promising technology because of their wide range of applications in industrial, environmental monitoring, etc. Owing to economic considerations, the nodes are simple and low cost. However, WSN is affected by different types of malicious attacks. The adversary compromises a node and drops all packets that are transmitted through this node. This process results in sensitive data being dropped or unable to be forwarded to sink node. The sink node in cold storage monitoring system makes decisions depending on the nodes' sensed data. When the sensed data about cold storage system not properly sent to sink node, it make incorrect decisions.

This impact the security and quality of products in cold storage system. Hence, there is a requirement for

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authentication technique to verify the sensor nodes as authentic or malicious during data communication. To improve the authentication performance of sensor nodes as compared to existing works, Energy and Trust Aware Multivariate Probit Classification (ETAMPC) Model is designed using Multivariate Probit Classification (MPC).

The ETAMPC Model is developed in order to enhance the safety and to preserve quality of products in cold storage. The ETAMPC Model increases the security and quality of products in cold storage as compared to existing techniques by selecting authenticated sensor nodes to route the sensed information using classification technique. The ETAMPC Model is proposed with the application of Multivariate Probit Classification (MPC).

The MPC classify the each sensor node in cold storage system as authenticated or malicious based on energy and trust values. On the contrary to existing works, MPC determines the probability for all sensor nodes fixed in cold storage system by considering two different metrics namely energy and trust value. This helps for MPC to classify the sensor nodes with higher accuracy and minimal time consumption as compared to existing works. The architecture diagram of ETAMPC Model is demonstrated in below Figure 2.

Figure 2 portrays the overall processes of ETAMPC Model to attain higher security on cold storage. As shown in figure, ETAMPC Model at first evaluates energy and trust value for every sensor node placed in cold storage. Then, ETAMPC Model classifies the sensor node as authentic or malicious with higher accuracy.

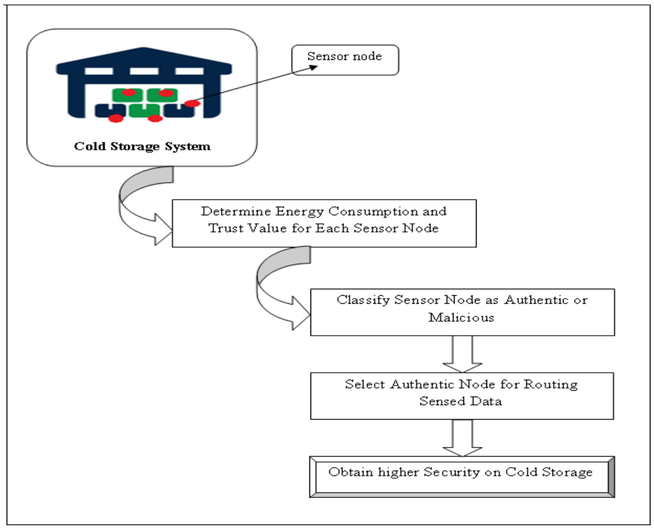

Figure 2 Architecture Diagram of ETAMPC Model for Secured Cold Storage

After classification, ETAMPC Model choose only an authentic sensor nodes to transmit collected data i.e. temperature, humidity, toxic gases and light intensity, etc to base station or sink node. The sensed data transmitted through authentic sensor nodes are not affected or dropped by malicious attacks. This helps for proposed ETAMPC Model to significantly monitor the change of temperature, humidity, etc to secure product in cold storage system. As a result, ETAMPC Model offers better performance in terms of classification accuracy, authentication time, energy consumption and security level for effective cold storage system monitoring. The detailed process of ETAMPC Model is shown in below.

A. *Multivariate Probit Classification Model*

The ETAMPC Model employed Multivariate Probit Classification (MPC) for accurately classifying the nodes in cold system as authentic or malicious.

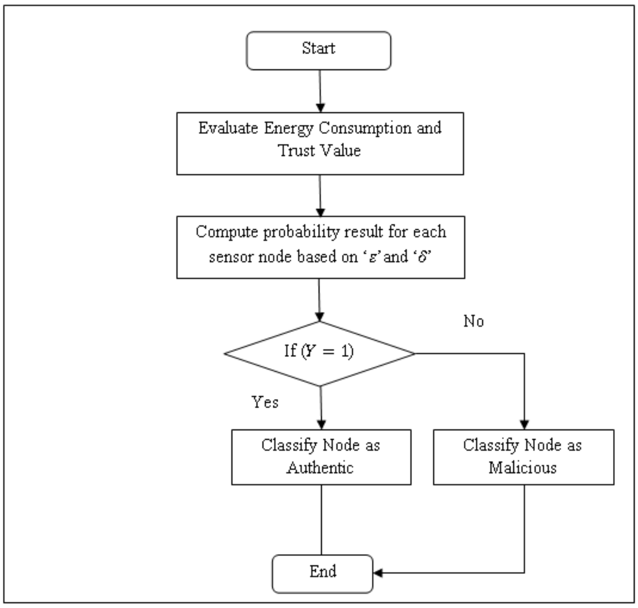

Figure 3 Flow Processes of MPC

The MPC is a type of regression where the dependent variable (output) only takes two values i.e. '1' or '0'. Here, the classification result of '1' indicates that the sensor node is authentic whereas '0' represents the node is malicious. The MPC estimates the probability that an observation with particular characteristics fall into specific category. Depending on measured probability results, then MPC perform classification with minimal complexity. The MPC is also called as binary classification model. The flow process of MPC is demonstrated in below Figure 3.

Figure 3 depicts the flow diagram of MPC to enhance security of cloud storage system. As illustrated in above figure, MPC Model evaluates energy and trust value for all sensor node fixed in cold storage system. Followed by, MPC determines probability result (i.e. measure of the likelihood that a sensor node is to be authenticated or malicious) using energy and trust values. Based on probability results, then MPC classifies the sensor node in cold storage system. If a probability result is '1', then MPC classifies the sensor node as authentic. Otherwise, MPC classifies the sensor node as malicious. The above processes of MPC Model help for proposed ETAMPC

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Model to get higher classification accuracy and also reduce the authentication time of sensor nodes as compared to conventional techniques.

Let us consider a cold storage system using WSN in the form of graph structure like '$G(V_i, E_i)$'. Here 'V_i' refers the number of sensor nodes in network whereas 'E_i' refers the links between sensor nodes. The sensor nodes in cold storage system is represented as '$\varphi_i = \varphi_1, \varphi_2, \varphi_3 \dots \varphi_n \in V$ that are lies within the transmission range 'r'. The MPC at first determines the probability for each sensor node 'φ_i' in cold storage system using below mathematical formulation,

$$\Pr(Y = 1|\varphi_i) = \phi(\varphi_i^T \beta) \quad (1)$$

From equation (1), 'Pr' represents probability whereas 'ϕ' refers a Cumulative Distribution Function (CDF) of the standard normal distribution. Here, parameters 'β' is calculated by maximum likelihood. In MPC, probability is a measure of the likelihood that an event will occur (i.e. sensor node is to be authenticated or malicious). From equation (1), probability is measured by considering two characteristics of sensor node namely energy 'ε' and trust level 'δ' in order to classify the sensor node with higher accuracy and lower time complexity.

The energy consumption is a one of key factor considered in WSN during the transmission of data between the nodes. When the amount of energy utilization for data transmission is more, then the routing of data packets will quickly fails due to the link failure. This process results in reduction of network's efficiency. Besides, malicious node in WSN may falsely route and drop all the packets and thus consume much amount of energy as compared to normal sensor nodes. Therefore, measuring energy consumption helps for MPC to efficiently classify the sensor nodes.

The energy consumption of sensor node is estimated by considering transmitting energy (α_ε) or receiving energy (γ_ε) in network. The energy level 'ε' of sensor node is measured using below formulation,

$$\varepsilon = p \times t \quad (2)$$

From equation (2), 'p' indicates the transmission power and t refers the time. Then, amount of time taken by a node to broadcast the sensed data between nodes is obtained as,

$$Tr_t = \frac{DP_S}{x} \quad (3)$$

From equation (3), Tr_t represents a time taken by sensor node for data transmission. Here DP_S is a data packet size and x denotes the bandwidth. Thus, the amount of energy consumed by sensor node '$\varepsilon_{\varphi i}$' is determined as,

$$\varepsilon_{\varphi_i} = p \times Tr_t \quad (4)$$

From equation (4), energy consumption is estimated for each sensor nodes in cold storage system. Furthermore, classification of sensor node is performed using MPC based on trust value measurement. The trust value is evaluated based on past history of sensor nodes (i.e. normal communication services rendered by nodes) in cold storage system. The trust value of a node is evaluated as the difference between data forwarded and dropped rate to the total number of data transmitted to neighboring nodes. Here, the data forwarded rate is computed as the number of data was forwarded to sensor node 'φ_j' by a node 'φ_i' to the total number of data received. The data forwarded rate 'FR_D' is mathematically formulated as,

$$FR_D = \frac{NDF\varphi_j}{NDR_{\varphi_i}} \quad (5)$$

From equation (5), 'NDR_{φ_i}' represents the number of data received by sensor node 'φ_i' and '$NDF\varphi_j$' indicates the number of data forwarded to the neighboring node 'φ_j' by sensor node 'φ_i'. In the same way, the data dropped rate is computed as the number of data that were dropped to the total number of data received by node 'φ_i'. From that, the data dropped rate is measured as,

$$DR_D = \frac{NDD\varphi_i}{NDR_{\varphi_i}} \quad (6)$$

From equation (6), '$NDD\varphi_i$' refers the number of data dropped by sensor node 'φ_i'. According, the trust value of each sensor node '$Trust_{MN_i}$' is determined as,

$$\delta_{\varphi_i} = \frac{FR_D - DR_D}{NDR_{\varphi_i}} \quad (7)$$

From equation (7), the trust value is measured for each node in a cold storage system. Then, the probability output of MPC is mathematically obtained as,

$$Y = \begin{cases} 1, \text{if } \varepsilon_{\varphi_i} \text{and } \delta_{\varphi_i} > T \\ 0, \quad \text{Otherwise} \end{cases} \quad (8)$$

From equation (8), 'ε_{φ_i}' and 'δ_{φ_i}' refers the determined energy and trust value of sensor node whereas 'T'denotes the predefined threshold energy and trust value. Followed

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by, MPC classify sensor nodes using below mathematical expression,

$$Y = \begin{cases} 1, & classify\ node\ as\ authenticated \\ 0, & classify\ node\ as\ malicious \end{cases} \quad (9)$$

By using the above mathematical expression (9), MPC classify the sensor node as authentic or malicious. After performing the classification, ETAMPC Model selects the authenticated nodes in order to transmit the collected data such as temperature, humidity without any falls for effective monitory of cold storage system and thereby attain higher secured and quality of products. The algorithmic processes of ETAMPC Model is depicted in below

```
// Energy and Trust Aware Multivariate Probit Classification Algorithm
Input: Number of sensor nodes in cold storage system φi = φ1, φ2, φ3 ..., φn
Output: Achieve improved security and quality for cold storage
Step 1:Begin
Step 2:   For sensor node 'φi'
Step 3:      Determine energy consumption level 'ε_φi'  using (4)
Step 4:      Compute trust value 'δ_φi'  using (7)
Step 5:      Obtain Probability result 'Y'  using (8)
Step 6:      If (Y = 1), then
Step 7:         Classify sensor node as authentic using (9)
Step 8:      Else
Step 9:         Classify sensor node as malicious using (9)
Step 10:     End If
Step 11:     Select authenticated sensor nodes to route collected data to sink node
Step 12:        Effective monitoring of environmental parameters such as temperature, humidity,
             toxic gases and light intensity to maintain the quality of the products in storage
Step 13:  End for
Step 14:End
```

Algorithm 1 ETAMPC Algorithm

Algorithm 1 presents the step by step processes of ETAMPC to get improved security and quality for cold storage system. By using the above algorithmic processes, ETAMPC model authenticates each sensor node in cold storage system as authentic or malicious through performing node classification with higher accuracy and minimal time. This supports for ETAMPC model to efficiently monitor the changes in environmental parameters such as temperature, humidity, toxic gases and light intensity in order to keep the quality of the products in storage. As a result, ETAMPC model attains the security and quality for products uphold in cold storage as compared to existing works.

IV. SIMULATION SETTINGS

In order to determine the proposed performance, ETAMPC model is implemented in NS-2 simulator using Capacity of Refrigerated Warehouses Dataset t. Dataset contains information of refrigerated warehouses by type and size group for states and US. It contains public, private and semiprivate warehouse capacity; gross space and usable space for refrigerator, cooler or freezer space. The ETAMPC model considers cold storage system using WSN with 1200m * 1200m network area to conduct simulation processes. The table 1 shows simulation parameters.

Table 1 Simulation Parameters

Simulation parameter	Value
Simulator	NS2.34
Number of sensor nodes	50, 100, 150, 200, 250, 300, 350,400,500
Simulation time	100s
Pause time	10s
Mobility model	Random Way Point
Transmission range	300m
Network area	1200m * 1200m
Data packets	10,20, 30, 40, 50, 60, 70,80,90,100
Number of runs	10

The simulation of ETAMPC model is carried out for many instances with respect to different number of sensor nodes and data packets for measuring proposed performance. The effectiveness of ETAMPC model is measured in terms of classification accuracy, authentication time, energy consumption and security level. The result of ETAMPC model is compared with existing ActiveTrust scheme [1] and Monitoring System for Frozen and Chilled Aquatic Products (MS-FCAP) [2].

V. RESULT AND DISCUSSIONS

In this section, the comparative result of ETAMPC model is discussed. The performance of ETAMPC model is compared with ActiveTrust scheme [1] and Monitoring System for Frozen and Chilled Aquatic Products (MS-FCAP) [2] respectively. The performance of ETAMPC model is analyzed along with the following metrics with the help of tables and graphs.

A. Performance of Classification Accuracy

In ETAMPC model, Classification Accuracy CA measured as the ratio of number of sensor nodes that are correctly classified as authorized or malicious as to the total number of nodes considered for simulation work. The classification accuracy is measured in terms of percentages (%) and acquired using below representation,

$$CA = \frac{NCC_{\varphi_i}}{N} * 100 \quad (10)$$

From equation (10), classification accuracy is determined with respect to various number of sensor nodes for securing cold storage. Here, 'N' denotes the total number of nodes and 'NCC_{φ_i}' indicates number of sensor nodes that are correctly classified as authorized or malicious. When

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classification accuracy is higher, the model is said to be more efficient.

Sample calculation:

ActiveTrust scheme: the number of correctly classified nodes is 35 and the total number of sensor nodes is 50. Then classification accuracy is estimated as,

$$CA = \frac{35}{50} * 100 = 70\ \%$$

MS-FCAP: the number of correctly classified nodes is 40 and the total number of sensor nodes is 50. Then classification accuracy is obtained as,

$$CA = \frac{40}{50} * 100 = 80\ \%$$

Proposed ETAMPC model: the number of correctly classified nodes is 48 and the total number of sensor nodes is 50. Then classification accuracy is formulated as follows,

$$CA = \frac{48}{50} * 100 = 96\ \%$$

Table 2 Tabulation for Classification Accuracy

Number of Sensor Nodes	Classification Accuracy (%)		
	ActiveTrust scheme	MS-FCAP	ETAMPC model
50	70	80	96
100	73	78	94
150	75	77	90
200	74	76	93
250	79	82	92
300	78	80	93
350	77	79	94
400	81	84	95
450	83	85	96
500	86	88	96

In order to measure the classification accuracy, ETAMPC model is implemented in NS-2 simulator by considering diverse number of sensor nodes in the range of 50-500. The simulation result of classification accuracy using ETAMPC model is compared against with existing ActiveTrust scheme [1] and MS-FCAP [2]. When considering 250 sensor nodes for simulation work, ETAMPC model gets 92 % classification accuracy whereas ActiveTrust scheme [1] and MS-FCAP [2] obtains 79 % and 82 % respectively. Thus, it is significant that the classification accuracy using ETAMPC model is higher as compared to other existing methods [1], [2]. The performance result of classification accuracy for obtaining secured cold storage is demonstrated in below.

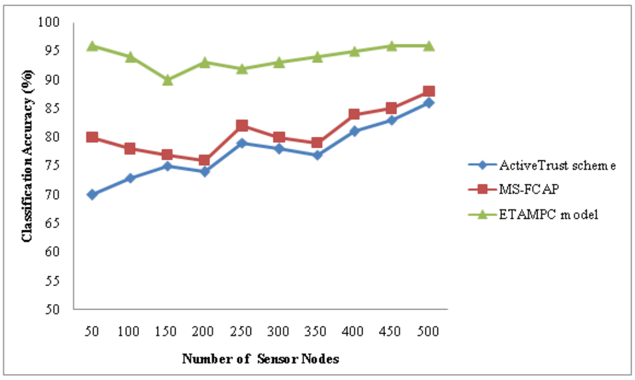

Figure 4 measurement of classification accuracy Vs number of sensor nodes

Figure 4 explains the comparative result of classification accuracy versus various numbers of sensor nodes in the range of 50-500 using three methods namely ActiveTrust scheme [1] and MS-FCAP [2] and ETAMPC model. As presented in the table, classification accuracy using proposed TGMDS-FE Technique is higher for attaining secured cold storage when compared to existing ActiveTrust scheme [1] and MS-FCAP [2]. This is due to application of MPC in proposed ETAMPC model where it computes probability for each node in cold storage system according to energy and trust value. This probability result assists for ETAMPC model to accurately classify the sensor nodes. Therefore, ETAMPC model enhance the classification accuracy by 21 % and 16 % as compared to conventional ActiveTrust scheme [1] and MS-FCAP [2] respectively.

B. Performance of Authentication Time

In ETAMPC model, Authentication Time (AT) measures the amount of time needed for authenticating the sensor node as authenticated or malicious in cold storage system. The authentication time is estimated in terms of milliseconds (ms) and obtained as,

$$AT = N * T(ASS) \quad (11)$$

From equation (11), authentication time is measured with respect to different number of sensor nodes. Here, 'N' represents the total number of nodes and '$T(ASS)$' refers time taken for authenticating single sensor node. While authentication time is lower, the method is said to be more efficient.

Sample calculation:

ActiveTrust scheme: Number of sensor node is 50 and the time taken for authenticating single sensor node is 0.28ms. then the authentication time is determined as follows,

$$AT = 50 * 0.28 = 14ms$$

MS-FCAP: Number of sensor node is 50 and the time

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taken for authenticating single sensor node is 0.16ms. Then the authentication time is obtained as follows,

$$AT = 50 * 0.31 = 16ms$$

Proposed ETAMPC model: Number of data packet is 50 and the time taken for routing the one data packet is 0.25ms. Then the authentication time is estimated as follows,

$$AT = 50 * 0.25 = 13ms$$

In order to compute the authentication time, ETAMPC model is implemented in NS-2 simulator using various number of sensor nodes in the range of 50-500. The simulation result of authentication time using ETAMPC model is compared against with existing ActiveTrust scheme [1] and MS-FCAP [2]. When employing 300 sensor nodes for performing simulation process, ETAMPC model obtains 21 ms authentication time whereas ActiveTrust scheme [1] and MS-FCAP [2] acquires 23 ms and 26 ms respectively. Accordingly, it is clear that the authentication time using ETAMPC model is lower as compared to other existing methods [1], [2]. The performance result of authentication time for secure cold storage is presented in below.

Table 3 Tabulation for Authentication Time

Number of Sensor Nodes	Authentication time (ms)		
	ActiveTrust scheme	MS-FCAP	ETAMPC model
50	14	16	13
100	17	19	15
150	20	21	18
200	22	24	20
250	24	28	22
300	23	26	21
350	25	30	24
400	26	27	25
450	25	28	23
500	29	31	26

Figure 5 portrays the simulation result analysis of authentication time versus different numbers of sensor nodes in the range of 50-500 using three methods namely ActiveTrust scheme [1] and MS-FCAP [2] and ETAMPC model. As shown in the table, authentication time using proposed TGMDS-FE Technique is lower for obtaining secured cold storage when compared to existing ActiveTrust scheme [1] and MS-FCAP [2]. This is because of application of MPC in proposed ETAMPC model in which it determines probability for every sensor node in cold storage system by using energy and trust value measurement. This probability result supports for ETAMPC model to authenticate the sensor nodes by classifying as malicious or authentic with minimal amount of time utilization.

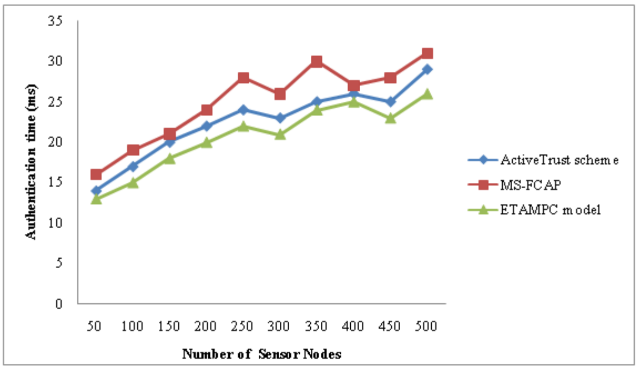

Figure 5 measurement of authentication time Vs number of sensor nodes

Thus, ETAMPC model lessens the authentication time by 8 % and 17 % as compared to conventional ActiveTrust scheme [1] and MS-FCAP [2] respectively.

C. Performance of Security Level

In ETAMPC model, Security Level '(SL)' of cold storage system is measured in terms of data loss rate. Thus, security level is determined as the ratio of number of data that are dropped to the total number of data considered for simulation work. The security level is evaluated in terms of percentage (%) and determined as,

$$SL = \frac{DP_D}{DP_S} * 100 \quad (12)$$

From equation (12), security level is calculated through data sent and received. Here, DP_D denotes the number of data dropped whereas DP_S refers total number of data assumed for performing simulation process. While security level is higher, the method is said to be more effective.

Sample calculation:

ActiveTrust scheme: the number of data dropped is 3 and the total number of data packets is 10. Then security level is computed as,

$$SL = \frac{3}{10} * 100 = 30\ \%$$

MS-FCAP: the number of data dropped is 2 and the total number of data packets is 10. Then security level is measured as,

$$SL = \frac{2}{10} * 100 = 20\ \%$$

Proposed ETAMPC model: the number of data dropped is 1 and the total number of data packets is 10. Then security level is evaluated as,

$$SL = \frac{1}{10} * 100 = 10\ \%$$

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To determine the security level of cold storage system, ETAMPC model is implemented in NS-2 simulator using diverse number of sensor nodes in the range of 50-500. The simulation result of security level using ETAMPC model is compared against with existing ActiveTrust scheme [1] and MS-FCAP [2]. When using 70 data packets for conducting simulation process, ETAMPC model attains 12 % data loss rate whereas ActiveTrust scheme [1] and MS-FCAP [2] gets 29 % and 26 % respectively. From that, it is expressive that the security level using ETAMPC model is higher as compared to other existing methods [1], [2]. The performance result of security level of cold storage system is depicted in below.

Table 4 Tabulation for Security Level

Number of Data Packets	Security Level (%)		
	ActiveTrust scheme	MS-FCAP	ETAMPC model
10	30	20	10
20	35	25	15
30	33	27	17
40	38	25	16
50	36	24	14
60	32	28	13
70	29	26	12
80	26	25	10
90	24	23	9
100	23	22	7

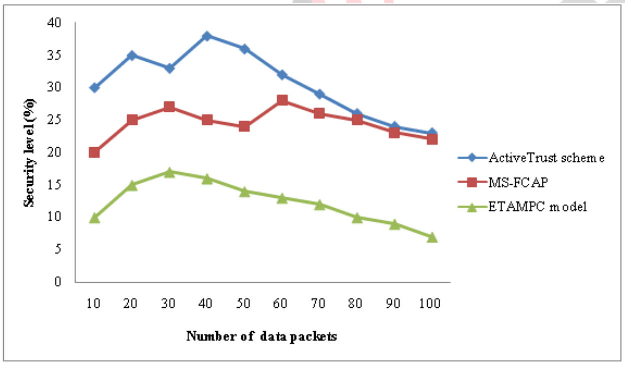

Figure 6 measurement of security level Vs number of sensor nodes

Figure 6 illustrates the result analysis of security level versus dissimilar numbers of data packets in the range of 10-100 using three methods namely ActiveTrust scheme [1] and MS-FCAP [2] and ETAMPC model. As depicted in the table, security level using proposed TGMDS-FE Technique is higher for cold storage when compared to existing ActiveTrust scheme [1] and MS-FCAP [2]. This is owing to application of MPC in proposed ETAMPC model. By using the concepts of MPC, ETAMPC model precisely classify the sensor nodes placed in cold storage system. With helps of classification results, then ETAMPC model choose the authentic node to broadcast the collected data to sink node. The data packets that are sent via authentic nodes are successfully reach sink node with minimum data loss rate compared to existing techniques. This helps for ETAMPC model significantly monitor the temperature, humidity changes and thereby obtains both safety and quality for products in cold storage compared to existing works. Hence, ETAMPC model increases the security level by 60 % and 50 % as compared to existing ActiveTrust scheme [1] and MS-FCAP [2] respectively.

D. Performance of Energy Consumption

In proposed Technique, the Energy Consumption (EC) estimates amount of energy employed to route sensed data (i.e. temperature, humidity, etc) of cold storage system to sink node. From that, energy consumption is determined as product of energy consumed by a single sensor node for routing gathered data and total number of sensor nodes in cold storage system. The energy consumption is evaluated in terms of Joules (J) and mathematically calculated as,

$$EC = N * EC_{SSN} \qquad (13)$$

From equation (13), 'N' indicates total number of sensor nodes and 'EC_{SSN}' refers the energy used by a single node to transmit data. While energy consumption is lower, the method is said to be more effective.

Sample calculation:

ActiveTrust scheme: amount energy consumed by a single node to transmit data is 0.8 and the total number of sensor nodes is 50. Then energy consumption is computed as follows,

$$EC = 0.8 * 50 = 40\ J$$

MS-FCAP: energy used by a single mobile node to broadcast data is 0.68 and the total number of sensor nodes is 50. Then energy consumption is calculated as follows,

$$EC = 0.68 * 50 = 34\ J$$

Proposed ETAMPC model: energy utilized by a single mobile node to routing data is 0.62 and the total number of sensor nodes is 50. Then energy consumption is measured as follows,

$$EC = 0.62 * 50 = 31\ J$$

To evaluate the energy utilization in cold storage system, ETAMPC model is implemented in NS-2 simulator using varied number of sensor nodes in the range of 50-500. The simulation result of energy consumption using ETAMPC model is compared against with existing ActiveTrust scheme [1] and MS-FCAP [2]. From table 5, when assuming 400 sensor nodes for carried outing simulation work, ETAMPC model gets 108J energy whereas ActiveTrust scheme [1] and MS-FCAP [2] obtains 188J and 132J respectively. As a result, it is descriptive that the energy consumption using ETAMPC model is lower as compared to other existing methods [1], [2]. The

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performance result of energy consumption is shown in below.

Table 5 Tabulation for Energy Consumption

Number of Sensor Nodes	Energy Consumption (J)		
	ActiveTrust scheme	MS-FCAP	ETAMPC model
50	40	34	31
100	70	56	50
150	90	64	59
200	108	78	74
250	123	93	88
300	135	120	99
350	168	116	112
400	188	132	108
450	185	144	113
500	190	155	115

Figure 7 presents the comparative result analysis of energy consumption versus different numbers of sensor nodes in the range of 50-500 using three methods namely ActiveTrust scheme [1] and MS-FCAP [2] and ETAMPC model. As demonstrated in the table, energy consumption using proposed TGMDS-FE Technique is lower when compared to existing ActiveTrust scheme [1] and MS-FCAP [2]. This is owing to usage of MPC in proposed ETAMPC model. With help of classification processes of MPC, ETAMPC model authenticates the sensor nodes in cold storage system as authentic or malicious.

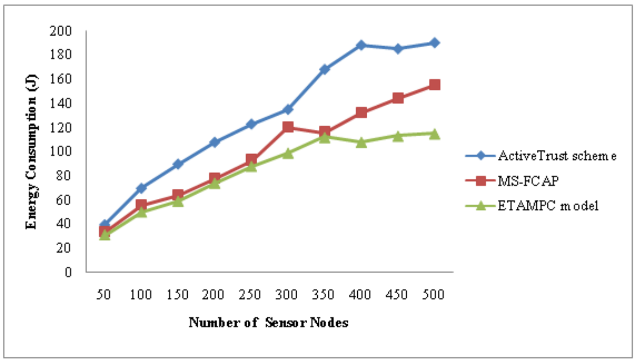

Figure 7 measurement of energy consumption Vs number of sensor nodes

Then, ETAMPC model picks only an authentic node to transmit sensed data to sink node and thereby avoids the malicious nodes during data communication. This helps for ETAMPC model to reduce the extra consumption of energy as compared to state-of-the-art works. Therefore, ETAMPC model decreases the energy consumption by 33 % and 12 % as compared to existing ActiveTrust scheme [1] and MS-FCAP [2] respectively.

VI. CONCLUSION

An effective ETAMPC model is designed with key objective of increasing classification performance of node authentication to obtain higher security for cold storage system. The aim of ETAMPC model is attained with designing of MPC. With the application of MPC processes, ETAMPC model verifies the sensor nodes in cold storage system as authentic or malicious during processes of data communication. Afterward, ETAMPC model routes the collected data to sink node by choosing authentic nodes with lower data loss. Hence, ETAMPC model efficiently observe the changes in environmental parameters such as temperature, humidity, toxic gases and light intensity in order to preserve the quality of the products in storage. Therefore, ETAMPC model achieves improved security and quality for products in cold storage as compared to state-of-the-art works. The performance of ETAMPC model is determined in terms of classification accuracy, authentication time, and security level and energy consumption as compared with two state-of-the-art works. With the simulation processes accomplished for ETAMPC model, it is significant that the classification accuracy is higher for node authentication in cold storage system when compared to state-of-the-art works. The simulation results shows that ETAMPC model provides better performance with an enhancement of security level and minimization of energy consumption of cold storage system as compared to the state-of-the-art works.

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