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Research paper

Fault Tolerance and QoS based Pervasive Computing using Markov State Transition Model

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Abstract

Fault-tolerance is significant in pervasive computing environments. Recently, few research works has been developed for reducing the fault, occurring in pervasive computing. However, there is a need for a fault tolerance mechanism to reduce the link failures and unwanted mobile node access (in pervasive computing environment). In order to overcome these limitations, Markov State Transition Based Fault Tolerance (MST-FT) Model is proposed. The main objective of MST-FT Model is to achieve resource efficient QoS in pervasive computing environment by avoiding the link failures and unwanted mobile node usages. Initially, the optimization of link failures is achieved by maintaining Markov chain of high energy mobile nodes on the wireless network communication path. The mobile nodes with higher energy and minimal drain rate are combined to form a chain in its corresponding path of communication in order to minimize the link failures in pervasive computing. Next, the inappropriate mobile node usage is avoided by selecting only the authorized mobile nodes for Markov chain construction to effective network communication, which resulting in improved fault tolerant rate. Therefore, MST-FT Model provides higher resource efficient QoS as compared to existing works. The performance of MST-FT Model is measured in terms of fault tolerant rate, execution time, energy consumption rate and quality of service level. The simulation results show that the MST-FT Model is able to improve the fault tolerant rate by 13% and also reduces the energy consumption rate of resource efficient QoS by 25%, when compared to previous works.

Keywords: *Fault-Tolerance; Pervasive Computing Environments; Quality of Service (QoS); Markov State Transition; Mobile Nodes.*

1. Introduction

Recently, Pervasive computing environment has attained great attention due to recent developments in portable low-cost light-weight devices which it emergent with short range and low power wireless communication networks. Furthermore, many research works has been designed for fault tolerance to attain better quality of services in pervasive computing. For example, A Novel Fault tolerant Service Selection Framework (FTSSF) was developed in [1] for providing the service anywhere at any time with minimal service delay, service recovery overhead and high success rate in case of fault. However, the link failure remained unsolved.

A dynamic parallel composition model was planned in [2] to ensure that resultant composition mechanism is dynamic in nature to adapt to the service nodes failure without compromising the quality of service with better fault error recovery time. But, energy utilization is higher.

Aspect-oriented middleware architecture was designed in [3] to reconfigure the pervasive computing systems for context-aware and application services. Aspect-oriented middleware architecture also fulfilled the pervasive computing systems needs like mobility, fault tolerance and service distribution. Though, privacy and security remained unsolved.

A proactive fault-tolerant routing scheme with clustering and self-elimination techniques was implemented in [4] to establish a route among mobile devices of varying mobility and MAC in pervasive environment.

A novel method was planned in [5] to improve adaptability and fault-resiliency by means of efficiently re-planning the end-to-end services in face of component failure or adverse changes in pervasive computing system. A Service Preference Selection Framework [6] was developed in pervasive computing for providing the information at any time without interruption and complete the execution of disrupted service in case of fault occurrence. However, the application failure remained unaddressed.

An ETS self-healing architecture was constructed in [7] to address the fault detection and fault recovery related issues in pervasive computing environment. But, the system failure, link failure remained addressed.

The Delay/Fault-Tolerant Mobile Sensor Network (DFT-MSN) for pervasive information gathering was presented in [8] where Fault Tolerance-Based Adaptive Data Delivery Scheme (FAD) employs the message fault tolerance that designates the importance of the messages. However, the transmission overhead and energy consumption was high.

The rest of the paper organized as follows. In section 2, a literature survey of different fault tolerance techniques designed for pervasive computing is presented. In section 3, the proposed MST-FT Model is explained with the help of neat architecture diagram. In section 4, simulation environment is discussed with exhaustive analysis of results described in section 5. In section 6, the concluding remarks were discussed.

2. Related works

A Novel concepts for fault detection was developed in [9] that employs three-dimensional array of features to capture spatial and temporal variability to be used by an anomaly analysis engine to immediately make an alert while abnormal behavior pattern is captured indicating some kind of software or hardware failure. A survey different techniques designed for ubiquitous fault-tolerant were explained in [10].
A new approach was introduced in [11] for using the application query workloads to recognize the best tradeoff between query communication costs and availability in data storage centric sensor network. Autonomic middleware architecture was designed in [12] for software component reconfiguration depending on ontology with fault-tolerance in ubiquitous computing environment. Though, network energy consumption and link quality that are relevant QoS requirements remained unsolved.
A service oriented seamless migration (SOSM) flexible communication protocol was introduced in [13] to provide the pervasive web services for users in pervasive computing environment. A Trust-based Secure Service Discovery (TSSD) model was designed in [14] for pervasive environment that allows secure and non-secure discovery and solves the communication as well as service sharing security issues. But, the security related issues remained unsolved and takes more battery power consumption.
The self-adaptive fault-tolerant mechanism (SAFTM) was designed in [15] that dynamically built according to different types of identified faults based on continuous monitoring and analysis of the component states. But, numerous factors may impact service reliability of SAFTM system. In [16], semantic matchmaking services identifies the appropriate resources which satisfy the needs. A novel architecture was developed in [17] for effective communication and identify the remote resource which is potential enough to support the requesting services.
A service selection approach based on QoS and user preferences was introduced in [18] for efficient and cost-effective QoS (Quality of Service) support in pervasive environment. An Efficient semantic Service discovery (EASY) was presented in [19] to achieve efficient, semantic, context- and QoS-aware service discovery in pervasive computing environment. A new QoS architecture was designed in [20] to achieve the promised resources in different sub networks of a ubiquitous network and to forecast the resource requirement of the application.
Based on the aforementioned techniques and methods presented, in this work we propose a novel framework called Markov State Transition Based Fault Tolerance (MST-FT) Model is proposed to avoid the link failures and unauthorized mobile node usage relating to access point in the pervasive computing environment.

3. Markov state transition based fault tolerance (MST-FT) model

Pervasive computing has the capability to access and update information anywhere, and anytime. In pervasive computing, a user interacts with the computer through the laptop, computers, tablets etc. Besides, resource efficient quality of services (QoS) is very significant in pervasive computing to provide the continuity of the service in spite of network failures. To achieve a good QoS and to ensure the continuity of the service, a new fault tolerance mechanism called Markov State Transition Based Fault Tolerance (MST-FT) Model is designed in pervasive computing environment.
Let consider a pervasive computing environment consisting of N independent mobile nodes. Each mobile node may move freely or remain stationary in its location. As well, each mobile node may connect, leave the network or fail at any time. Due to the mobility of nodes, the link failure occurs in communication path which affects the QoS in pervasive computing environment. Therefore, a link failure in mobile node communication is needs to be avoided for effective communication of nodes to achieve better QoS in pervasive environment. In addition, a Mobile user in pervasive environment is wait to access locally hosted resources and services anytime and anywhere, which directs to serious security issues. Hence, unauthorized mobile node access is also needs to be avoided for achieving better QoS. In order to overcome these limitations, The MST-FT Model is proposed.
The main goal of MST-FT Model is to lessen the link failures and to avoid unauthorized mobile node usage relative to access point in the pervasive computing environment. The MST-FT Model is used Markov State Transition Model for achieving the better QoS in pervasive computing environment. The architecture diagram of MST-FT Model is shown in figure 1.

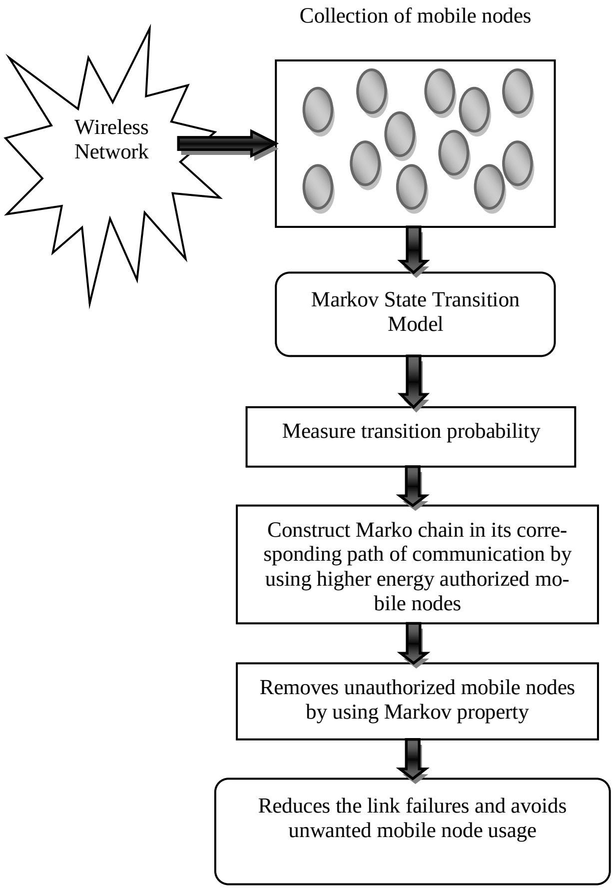

Fig. 1: Architecture Diagram of MST-FT Model.

As shown in the above figure 1, pervasive computing environment comprises of collection of mobile nodes. At first, MST-FT Model measures transition probability of mobile nodes to connect the mobile nodes in case of any link failures occurs in its communication path. Next, with the help of measured transitional probability, MST-FT Model creates a Marko chain in its corresponding path of communication by using only higher energy authorized mobile nodes. Finally, MST-FT Model removes unauthorized and lower energy mobile nodes by using Markov property which resulting in efficient communication of mobile nodes. Therefore, MST-FT Model significantly reduced the link failures and unnecessary mobile node usage in pervasive computing environment.

3.1. Avoiding unwanted mobile node usage

The MST-FT model assumed that any node in this network will not listen to any request-to-send (RTS) request until it has a specific number of nodes within its range. In addition, the node will have a fixed period of time before it replays a Clear-to-Send (CTS) message which may help in reducing the number of malicious nodes (i.e. unauthorized mobile node usage) in the pervasive environment.
To avoid the unauthorized mobile node access, MST-FT Model initially identifies average number of authorized mobile node in pervasive environment. With the help of this, then it finds unau-

thorized mobile node access relating to the access points. After that, MST-FT Model constructs Markov chain for reliable communication to attain resource efficient QoS in pervasive computing environment.

To find the average number of authorized mobile node in pervasive computing environment, the probabilities of authorized mobile node usage for each state is first estimated. Therefore probability of zero authorized mobile nodes in a pervasive computing environment is mathematically formulated as follows,

$$\mathrm{P}_{0,\mathrm{authorized}} = \sum_{j=1}^{N} \mathrm{S}_{ij} \quad (1)$$

From the equation (7), N represents the maximum number of mobile nodes and $\mathrm{S}_{ij}$is the probability of transition states ij.Besides, the probability of one authorized mobile node in a pervasive computing environment is expressed as below,

$$\mathrm{P}_{1,\mathrm{authorized}} = \sum_{j=0}^{N-1} \mathrm{S}_{ij} \quad (2)$$

Thus, the probability of authorized mobile node in pervasive computing is formulated as

$$P_{i,authorized} = \sum_{j=0}^{N-i} S_{ij}, \text{ Where } 0 \leq i,j \leq N \quad (3)$$

By using the equation (9), the average number of authorized mobile node in pervasive environment is obtained which is mathematically formulate as follows,

$$Avg_{authorized} = \sum_{j=0}^{N} iS_{ij} \quad (4)$$

On the other hand, MST-FT Model also have found out the zero probability of unauthorized mobile node usage relating to access points in pervasive environment which is formulated as follows,

$$P_{unauthorized,0} = \sum_{i=0}^{N} S_{ij} \quad (5)$$

In addition, the probability of one unauthorized mobile node in pervasive environment is given by

$$P_{unauthorized,1} = \sum_{i=1}^{N-1} S_{ij} \quad (6)$$

Generally, the probability of unauthorized mobile node in pervasive environment is given by

$$P_{unauthorized,j} = \sum_{j=1}^{N-j} S_{ij} \text{ Where } 0 \leq i,j \leq N \quad (7)$$

By applying the following formula, the unauthorized mobile node usage in pervasive environment will be obtained which is mathematically formulated as,

$$Avg_{unauthorized} = \sum_{j=0}^{N} jS_{ij} \quad (8)$$

After finding the authorized mobile nodes, MST-FT Model used Markov state transition model for effective communication of mobile nodes to achieve good QoS which detailed explained in next section.

3.2. Markov state transition model

After discovering the authorized mobile nodes in pervasive environment, MST-FT Model is used Markov State Transition Model for avoiding the link failures occurs in its communication path. The Markov State Transition is the process in which changes takes place one state to other state space. While the link failures is occurs in pervasive computing environment, the mobile node transitioning from one state to another (i.e. one mobile node to another mobile node in its corresponding path) for efficient communication. In Markov State Transition Model, one-step transition represents the probability of transitioning from one state to another in a single step. The Markov chain is said to be time homogeneous if the transition probabilities from one mobile node to another are independent of time t which is formulated as,

$$P_{ij} = Pr\{X_t = j/X_{t-1} = i\} \quad (9)$$

From the equation (9), the transition probability matrix 'p' is the matrix comprising of the one-step transition probabilitiesP_{ij} of mobile nodes. Thus, the N-step, transition probability is the probability of transitioning from mobile node i to mobile node$j$, in N steps which is expressed as,

$$P_{ij}^{(N)} = Pr\{X_{t+N} = j/X_t = i\} \quad (10)$$

To transition from mobile node 'i' to mobile node 'j' in N steps, the process can first transition from i to r in N-K steps and then transition from 'r' to ' j' in step K steps, which is defined as,

$$P_{ij}^{(N)} = \sum_{n\epsilon S} P_i^k, P_j^{N-k} \text{ Where} k = 0,1,2..n \quad (11)$$

From the equation (11), S indicates the state space transition, 'n' represents number of mobile nodes in pervasive computing environment. With the aid of determined transition probability of mobile nodes, then MST-FT Model constructs Markov chain by selecting the higher energy authorized mobile node in pervasive environment. The mobile nodes in pervasive computing environment are used Markov chain model and transition probability in order to avoid the link failures in communication.

The Markov Chain model is employed in MST-FT Model to generate a chain of high energy and minimal drain rate nodes for efficient wireless network communication in pervasive computing. In Markov Chain model, the next state of the system depends only on the present state, not on previous states. Such a way, the state transition is efficiently performed in MST-FT Model. The authorized mobile nodes with higher energy are united to construct a Marko chain in its corresponding path of communication to minimize the link failures and to avoid the unauthorized mobile node usage in pervasive computing environment which is formulated as follows,

$$Markovchain = \left(MN_{q+1} = mn \middle| mn_1 = MN_1, mn_2 = MN_2 \ldots\ldots MN_n = mn_n\right) \quad (12)$$

From the equation (12), the probable chain for diverse number of mobile nodes is obtained. The Markov Chain model concerns the higher energy authorized mobile nodes which is adjacent to one another node. By using this, the higher energy nodes in pervasive computing environment are grouped to form a chain using MST-FT Model for efficient communication of mobile nodes which in turn reduces the link failures and also unwanted mobile node usage. Therefore, the MST-FT Model provides a resource efficient quality of service in pervasive computing environment. The following Figure 2 shows a simple Markov chain with three states (i.e. mobile modes) for efficient communication.

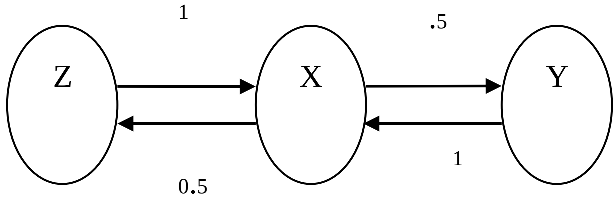

Fig. 2: a Markov Chain of Three Mobile Nodes.

The above figure 2 shows the Markov chain of three mobile nodes and their transition probability of communication while a link failure is occur in its communication path. From the Figure 2, the numbers on the links denote the transition probabilities. From the middle mobile node X, we precede with equal probabilities of 0.5 to either mobile node Y or Z. From either X or Y, we proceed with probability 1 to mobile node X. Therefore, the transition probability matrix of this Markov chain is mathematically formulated as,

$$\text{transition probability matrix} = \begin{pmatrix} 0 & 0.5 & 0.5 \\ 1 & 0 & 0 \\ 1 & 0 & 0 \end{pmatrix} \quad (13)$$

The Markov chain includes of N states at one specified time, thus the probable entry P_{ij} of the next sate time 'j' depends only on the current state 'i'. According to this, the property of the Markov chain is mathematically formulated as follows,

$$\forall\ i, j, P_{ij} \in [0,1] \quad (14)$$

By using the property of Markov chain, the unauthorized and lower energy mobile nodes in communication path are removed efficiently. This in turn provides the reliable communication with the longer network lifetime for efficient way of sharing the resources in the pervasive computing environment. Therefore, the MST-FT Model provides QoS rendering strategy to make the communication of wireless network more towards the user demand and maximize the resource sharing ability in pervasive computing environment. The algorithmic process of Markov State Transition Based Fault Tolerance model is shown in figure 3.

// Markov State Transition Based Fault Tolerance Algorithm
Input: Mobile Nodes $(MN_1, MN_2, \dots, MN_n)$
Output: Reduced link failures and unwanted mobile node usages.
BEGIN
Step 1: Evaluate the number of authorized mobile node by using (4)
Step 2: Evaluate the number of unauthorized mobile node by using (8)
Step 3: Measure one step transition probability of mobile nodes using (9)
Step 4: Measure N-step transition probability of mobile nodes using (11)
Step 5: Authorized mobile nodes with higher energy are combined to construct a Marko chain in its corresponding path for efficient communication by using (12)
Step 6: The lower energy nodes and unauthorized mobile nodes in communication path are efficiently removed according to the property of Markov chain by using (14)
Step 7: Provides resource efficient QoS
END

Fig. 3: Markov State Transition Based Link Failure Reduction Algorithm.

As shown in above figure 3, Markov State Transition Based Link Failure Reduction Algorithm initially identifies the number of authorized and unauthorized mobile nodes in order to avoid the unwanted mobile node usage relative to access points in pervasive environment.

Then, it measures one step transition probability and N-step transition probability of mobile nodes to communicate the mobile nodes in case of any link failures occurs in its communication path. With the help of determined transition probability, after that MST-FT Model constructs Markov chain by choosing the higher energy authorized mobile node in its corresponding path of communication, which results in reduced link failures and inappropriate mobile node. Therefore, finally MST-FT Model provides resource efficient QoS in pervasive computing environment.

4. Simulation setting

The Markov State Transition Based Fault Tolerance (MST-FT) Model is implemented in NS-2 simulator. The effectiveness of MST-FT model is compared against with existing two methods namely dynamic parallel composition model [1] and fault tolerant service selection framework (FTSSF) [2]. The simulation parameters that are used for conducting experimental works are shown in Table 1.

Table 1: Simulation Parameters

Simulation factor	Value
Mobility	10 to100 m/s
Number of mobile nodes	50, 100, 150, 200, 250, 300, 350,400,500
Simulation time	100s
Pause time	10s
Mobility model	Random Way Point Model
Transmission range	300m
Network area	1200m * 1200m
Number of Users	1-1000

The performance of MST-FT Model is measured in terms of fault tolerant rate, execution time, energy consumption rate and quality of service level.

5. Results and discussions

In this section, the result analysis of MST-FT Model is estimated. The efficiency of MST-FT Model is compared against with dynamic parallel composition model [1] and Fault tolerant Service Selection Framework (FTSSF) [2] respectively. The performance of MST-FT Model is evaluated along with the metrics with the help of tables and graphs.

5.1. Measurement of fault tolerant rate

In MST-FT Model, fault tolerant rate is defined as the rate at which the occurrence of faults gets avoided. Besides, fault tolerant rate is defined as ratio of number of mobile node not affected by the fault to the total number of mobile nodes taken. The fault tolerant rate is measured in terms of percentages (%) and mathematically formulated as,

$$\text{Fault tolerant rate} = (\text{number of mobile nodes not affected by the fault} / \text{Total number of mobile nodes taken}) * 100 \quad (15)$$

From the above equation (15), the fault tolerant rate was obtained. In MST-FT Model, fault tolerant rate denotes the avoidance of the unwanted mobile node usages and efficient communication of mobile nodes in case of any link failures occurs in its communication path. While the fault tolerant rate is higher, the method is said to be more efficient.

Table 2: Comparison of Fault Tolerant Rate with different methods

Number of Mobile Nodes	Fault Tolerant Rate (%)		
	Dynamic Parallel Composition Model	FTSSF	MST-FT Model
50	72.12	79.26	88.25
100	74.58	81.56	89.63
150	75.95	82.69	90.14
200	76.68	85.47	92.58
250	78.52	86.96	93.47
300	79.13	88.52	95.36
350	80.14	89.32	96.23
400	81.24	90.14	97.58
450	83.66	92.36	98.36
500	84.36	93.56	99.63

Table 2 depicts the fault tolerance rate results of three methods namely Dynamic Parallel Composition Model [1], FTSSF [2] and MST-FT Model based on different number of mobile nodes taken in the range of 50-500.While the 150 mobile nodes are taken for providing a quality of service, the proposed MST-FT Model has achieved 90 % fault tolerance rate, whereas Dynamic Parallel Composition Model, FTSSF achieves 75 %, 82 % respectively. Thus, fault tolerance rate using proposed MST-FT Model is higher, when compared to other existing methods.

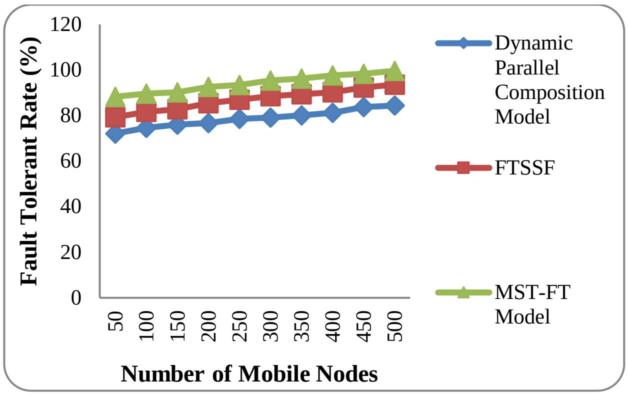

Fig. 4: Comparison of Fault Tolerant Rate with Different Methods.

Figure 4 demonstrates the impact of fault tolerance rate versus diverse number of mobile nodes in the range of 50-100. As illustrated in figure, proposed MST-FT Model provides better fault tolerance rate as compared to Dynamic Parallel Composition Model [1], FTSSF [2]. Besides, while increasing in the number of mobile nodes for a resource efficient quality of service in pervasive environment, the fault tolerance rate, was also gets increased using all the three methods. But comparatively, the fault tolerance rate using proposed MST-FT Model is higher compared to other existing methods. This is because of the application of Markov State Transition Based Fault Tolerance Algorithm in MST-FT Model where it takes authorized mobile nodes with higher energy to form a Marko chain in its corresponding path for efficient communication in pervasive environment. This in turn reduces the link failures and unwanted mobile node usage relating to access points which resulting in better quality of service and resource sharing. Therefore, proposed MST-FT Model improves the fault tolerance rate by 17% when compared to Dynamic Parallel Composition Model [1] and 8% when compared to FTSSF [2] respectively.

5.2. Measurement of execution time

In MST-FT Model, execution time measures the amount of time taken to construct the Markov chain for efficient communication to attain a resource efficient quality of service in pervasive computing environment.

$$Execution time = No. of sensor node * Time\ (to\ form\ Markov chain) \qquad (16)$$

From the equation (16), the time taken for resource efficient quality of service is obtained. While the execution time is lower, the method is said to be more efficient.

Table 3: Comparison of Execution Time with Different Methods

Number of Mobile Nodes	Execution Time (ms)		
	Dynamic Parallel Composition Model	FTSSF	MST-FT Model
50	25.1	19.3	14.6
100	30.5	25.6	20.4
150	36.9	30.5	25.9
200	42.4	37.8	31.7
250	48.6	43.2	36.5
300	55.7	48.4	42.4
350	61.5	55.3	47.9
400	67.3	61.7	52.6
450	72.1	66.5	58.1
500	78.6	71.6	65.3

Table 3 portrays the comparative result analysis of time taken for resource efficient quality of service using three methods namely Dynamic Parallel Composition Model [1], FTSSF [2] and MST-FT Model. While the 100 mobile nodes are taken for providing a user services in pervasive environment, the proposed MST-FT Model has attained 20.4 ms execution time, whereas Dynamic Parallel Composition Model, FTSSF attains 30.5ms, 25.6ms respectively. Therefore, execution time using proposed MST-FT Model is lower when compared to other existing methods.

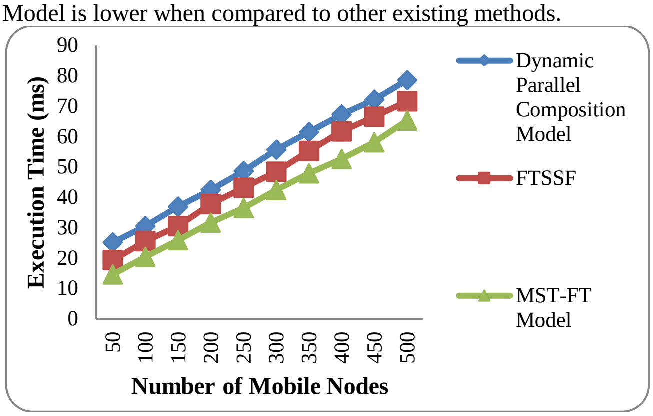

Fig. 5: Comparison of Execution Time with Different Methods.

Figure 5 shows the impact of execution time versus dissimilar number of mobile nodes in the range of 50-100. As illustrated in figure, proposed MST-FT Model provides better execution time for resource efficient quality of service as compared to Dynamic Parallel Composition Model [1], FTSSF [2]. As well, while increasing the number of mobile nodes for a achieving better quality of service in pervasive environment, the execution time is also gets increased using all the three methods. But comparatively, the execution time using proposed MST-FT Model is lower compared to other existing methods. This is due to the application of Markov State Transition Model in MST-FT Model. In MST-FT Model, the Markov chain model used higher order transitional probabilities that precisely remove the lower energy and unauthorized mobile nodes in communication path. The removal of the lower and unwanted energy node results in achieving the good QoS and also takes minimum time for providing their services in pervasive environment. As a result, proposed MST-FT Model reduces the execution time by 36%, when compared to Dynamic Parallel Composition Model [1] and 18% when compared to FTSSF [2] respectively.

5.3. Measurement of energy consumption rate

In MST-FT Model, the energy consumption rate measures energy consumed by the each mobile node and to reach sink node 'S' and number of high energy mobile nodes are selected to form the Markov chain in network. The energy consumption rate is measured in terms joule (J) and mathematically formulated as follows,

$$Energy\ consumption = EC_s * Total_s \qquad (17)$$

From the equation (17), the energy consumed by single mobile node $EC_s$and number of mobile node $Total_s$is obtained. In MST-FT Model, the energy consumption rate measures the amount of energy taken for achieving resource efficient quality of services in pervasive computing environment. While the energy consumption is lower, the method is said to be more efficient.

Table 4: Comparison of Energy Consumption Rate with Different Methods

Number of Mobile Nodes	Energy Consumption Rate (J)		
	Dynamic Parallel Composition Model	FTSSF	MST-FT Model
50	41.56	35.12	28.69
100	43.69	38.46	31.26
150	45.14	40.36	33.21
200	48.47	42.15	36.98
250	50.41	44.36	38.14
300	53.98	47.98	41.02
350	55.04	50.15	43.54
400	59.17	52.69	45.33
450	61.36	55.36	48.23
500	65.66	57.14	51.47

The above Table 4 represents the amount of energy taken for providing a resource efficient quality of service using three methods namely Dynamic Parallel Composition Model [1], FTSSF [2] and MST-FT Model based on different number of mobile nodes taken in the range of 50-500.While the 200 mobile nodes are taken for sharing the resources and satisfying the user demand in pervasive environment, the proposed MST-FT Model has consumes 36.98J energy, whereas Dynamic Parallel Composition Model, FTSSF consumes 48.47J, 42.15J respectively. Hence, energy consumption rate using proposed MST-FT Model is lower, when compared to other existing methods.

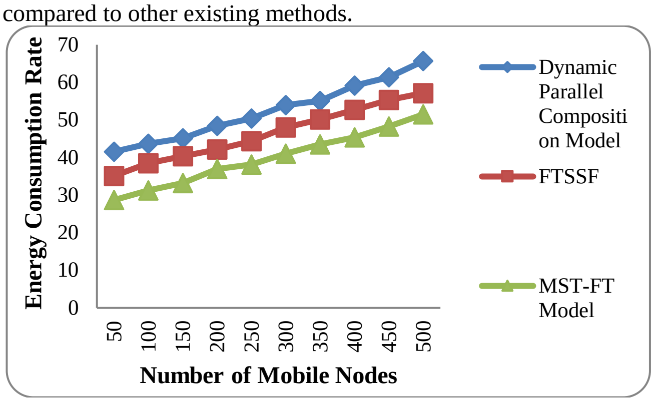

Fig. 6: Comparison of Energy Consumption Rate with Different Methods.

The above Figure 6 explains the impact of energy consumption versus different number of mobile nodes in the range of 50-100. As illustrated in figure, proposed MST-FT Model provides better energy consumption rate for achieving improved quality of services as compared to Dynamic Parallel Composition Model [1], FTSSF [2]. In addition, while increasing the number of mobile nodes for a resource efficient quality of service in pervasive environment, the energy consumption rate is also gets increased using all the three methods. But comparatively, the energy consumption rate using proposed MST-FT Model is lower compared to other existing methods. This is because of the application of Markov State Transition Based Fault Tolerance Algorithm in MST-FT Model in which by using the property of Markov Chain, the higher energy with minimal drain rate mobile nodes are combined for generating the chain for effective communication. Therefore, proposed MST-FT Model reduces the energy consumption rate by 33%, when compared to Dynamic Parallel Composition Model [1] and 17% when compared to FTSSF [2] respectively.

5.4. Measurement of quality of service level

In MST-FT Model, the quality of service level measures the ability of network to achieve better QoS rendering strategy to make the communication of wireless network more towards the user demand and maximize the resource sharing ability in pervasive computing environment. The quality of service level is measured in terms of percentages (%).While the quality of service level is higher, the method is said to be more efficient.

Table 5: Comparison of Quality of Service Level with Different Methods

Methods	Quality of Service Level (%)
Dynamic Parallel Composition Model	76.52
FTSSF	85.47
MST-FT Model	93.26

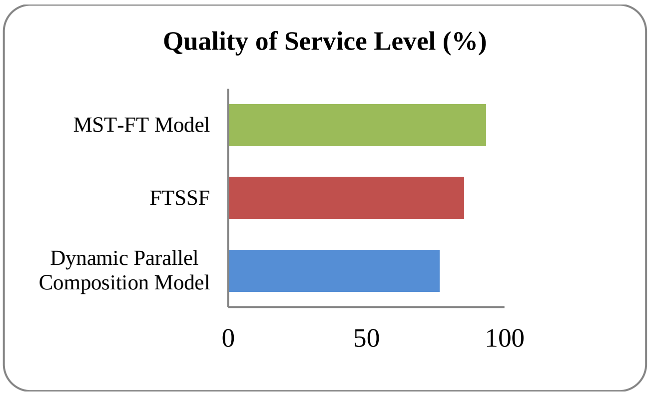

Fig. 7: Comparison of Quality of Service Level with Different Methods.

Table 5 and Figure 7 reveal the impact of quality of services level of three methods namely Dynamic Parallel Composition Model [1], FTSSF [2] and MST-FT Model. As illustrated in figure, proposed MST-FT Model provides quality of services level as compared to Dynamic Parallel Composition Model [1], FTSSF [2]. This is because of the application of Markov State Transition Based Fault Tolerance Algorithm in MST-FT Model, where Markov Chain is constructed for effective communication of mobile nodes by using Markova state transition model. The Markova state transition model evaluates the transition probability to commune the mobile nodes in case of any link failures occur in its communication path. This in turn helps in providing the resource efficient QoS in pervasive computing environment. Therefore, proposed MST-FT Model improves the quality of services level by 20% when compared to Dynamic Parallel Composition Model [1] and 8% when compared to FTSSF [2] respectively.

6. Conclusion

An effective novel framework called Markov State Transition Based Fault Tolerance (MST-FT) Model is developed to minimize the link failures and inappropriate mobile node usage relating to access point in the pervasive computing environment. The key aim of MST-FT Model is to achieve resource efficient QoS in pervasive computing environment. The objective of MST-FT Model is attained via reducing the link failures and inappropriate mobile node usage in pervasive computing environment. Initially, MST-FT Model determines transitional probability to connect the mobile nodes in case of any link failures occur in its communication path of network. After that, MST-FT Model builds a Marko chain in its corresponding path of communication with the assist of measured transitional probability. Finally, MST-FT Model eliminates unwanted and lower energy mobile nodes from the communication path by using the Markov property, which results in reduction of the link failures and inappropriate mobile node usages. The effectiveness of MST-FT Model is tested with the metrics such as fault tolerant rate, execution time, energy consumption rate and quality of service level. With the simulations conducted for MST-FT Model, it is observed that the as fault tolerant rate and quality of service level is provided more accurate results as compared to state-of-the-art works. The simulation results demonstrate that MST-FT Model is provides better performance with an improvement of fault tolerant rate by 13% and the reduction of energy consumption rate by 25% when compared to the state-of-the-art works.

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