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A Genetic Algorithm based Check pointing and Failure Recovery Scheme in Wireless Sensor Network

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***Abstract*—**Mobile nodes are failure prone. An efficient check pointing technique and a failure recovery scheme together can make a Wireless Sensor Network fault-tolerant. For efficient recovery, information of a mobile host should be kept in an organized manner. Efficiency of a recovery scheme can be measured in terms of time and cost. Mobile nodes move randomly causing handoff. Information of a single mobile host gets scattered over a number of mobile support stations that can be at closer or further distance. Recovery time and cost primarily depend on number of mobile support stations from which information to be collected as well as distance among them. Larger the distance, longer the time for communication through message passing. Number of mobile support stations from which information to be recovered and distance among them can be delimited by keeping a Genetic Algorithm threshold value and a distance threshold value respectively in each mobile host. Recovery scheme proposed here applies both the measures. Our work optimizes both failure-free and failure-recovery operation costs.

***Keywords*—**Checkpoint, recovery, fault tolerance, genetic algorithm,etc

I. INTRODUCTION

Distributed systems are becoming mobile distributed systems in today's era of technology evolution. Wireless Sensor Networks are prone to failure. Fault tolerance is an essential characteristic of such systems. A number of efficient checkpointing algorithms for WSN are proposed but most of them are lacking in efficient failure recovery. MHs fails quite frequently and volatile memory information gets lost [1]. Stable storage of MSSs are non volatile. Hence MH saves data and sends to its current MSS. As MHs move randomly, current MSS gets changed and information of a single MH gets dispersed over many MSSs. To collect scattered information with minimum time and effort an efficient recovery scheme is required. Some of the relevant works are discussed in the literature review section II. Section III describes the system model through which the proposed work is explained.

II. RELATED WORK

In [2], Sapna E.George, Ing-Ray Chen and Ying Jin present the idea about recovery scheme for the Wireless Sensor Networks based on checkpointing in which checkpoint is only taken after a threshold of mobility handoffs has been exceeded. The Optimal threshold is governed by the failure rate, log arrival rate and the mobility rate of the mobile nodes [3]

In [4], R.E. Ahmed and A Khaliq proposed a region based recovery information management scheme for the Fault Tolerant Wireless Sensor Networks. There are region managers who manage information of all MHs under that region. If region size is large, region manager gets overloaded with information of a large number of MHs. As a result information recovery will be complex. If region manager fails due to any reason total information loss will be there. Moreover failure free operation cost is also not optimized.

In [5], Jiang et.al, presented an efficient recovery scheme for WSN. Communication is at MH level to reduce recovery cost. But number of messages and overhead related to this will be huge causing wastage of memory and bandwidth. Hence it is not suitable for resource constrained WSN.

In [6], Juang et.al describes an efficient rollback recovery algorithm for distributed Wireless Sensor Networks. In this algorithm the failed MHs only need to rollback one and they can resume operation immediately as they don't need to wait for any coordination message from other MHs. MHs communicates through MSSs

In the proposed scheme instead of concept of region, distance between MSSs is considered as a key factor. We have tried to reduce distance between recovery MSS and other MSSs from which recovery information is to be fetched. Thus recovery cost becomes low. Failure free operation cost is also optimized in a way as information of MHs are transferred between MSSs with smaller distance in between.

III. SYSTEM MODEL

Wireless Sensor Network consists of n number of mobile nodes and m number of Mobile support stations, where n>>m. Mobile nodes are connected through wireless network and mobile support stations are connected through wired network. Communication links connecting MHs & MSSs are assumed to be FIFO. Messages take arbitrary but finite amount of time during transmission. There are no synchronized clocks or shared memory among nodes. Mobile nodes save checkpoints. Each MH keeps Genetic Algorithm threshold value and distance threshold value. If any threshold value is exceeded checkpoint data is forwarded to current MSS. MHs move randomly in different movement patterns [7].

Notations

1. MH = mobile host
2. MSS = mobile support station
3. h_c = Genetic Algorithm count
4. h_T = Genetic Algorithm threshold
5. M_o = 0, 1. 0 = moves across cells, 1 = moves within a cell.
6. $distance_{between}$ = geographical distance between MSS_{start} and MSS_c .
7. d_T = distance threshold
8. MSS_c = current MSS
9. $MSS_{traversed}$ [m] = List of MSSs an MH traverses during a checkpoint interval
10. MSS_{start} = The MSS from which an MH starts moving at the beginning of a checkpoint interval.
11. MSS_{finish} = The MSS in which permanent checkpoint is saved if $h_c > h_T$.
12. $MSS_{recovery}$ = The MSS in which failed MH recovers.
13. MH_status = -1, 0, 1. -1 = failed, 0= disconnected, 1 = connected

IV. PROBLEM DEFINITION

MHs move randomly causing handoff. Hence checkpoints of a single MH are scattered in different MSSs [8]. If an MH fails, recovery information are to be collected from different MSSs. If distance between $MSS_{recovery}$ and the MSS $_{start}$ is large, then recovery time will be more. In region based recovery scheme, region manager is the centralized control [9]. Hence it may get overloaded. Moreover if it fails, recovery is not possible.

A. Proposed Solution

If $distance_{between}$ or h_c exceed corresponding threshold value, MSSs in MH's traversed list send recovery information to MSS_c.

Thus if an MH fails at any point of time, maximum $distance_{between}$ of $MSS_{recovery}$ and MSS_{start} will be d_T and maximum number of MSSs from which recovery information to be collected gets is h_T. Hence recovery time and cost both are much less. Here maximum of d_T or h_T number of MSSs perform the role of region manager omitting possibility of centralized failure.

B. Basic Concept of Proposed Scheme

In a Wireless Sensor Network Mhs move randomly causing Genetic Algorithm and leaving checkpoint data scattered in different MSSs. If an Mh fails efficient recovery technique can help it to recover and continue normal execution with minimum time and cost [10]. As MHs can move in different movement patterns [1], following cases are to be considered:

Case 1: Mhs move in intercell or combination movement pattern:

If any one of Genetic Algorithm count or $distance_{between}$ exceeds respective threshold value at ith MSS, checkpoint data of the MH is transferred from $MSS_{traversed}$ to MSS_i.

Case 2: Mhs move in intracell movement pattern: no need to transfer checkpoint data as its MSSstart will be its MSSrecovery if the MH fails.

V. ALGORITHM

h_c = 0; h_T , $distance_{between}$ = 0; d_T, m = 0, $MSS_{traversed}$ [m], $MSS_{traversed}$;

1. if (MH_status = = 1){
2. if (M_o = = 1) {
   1.1 $distance_{between}$ ++, $MSS_{traversed}$ ++, h_c ++, m++ ;
3. repeat 1.1 till ($h_c \le h_T$ || $distance_{between} \le d_T$);
4. for (i = 0 ; i < m ; i ++)
5. {
   5.1. transfer checkpoint data of MH_i $MSS_{traversed}$ [i] to $MSS_{traversed}$ [m] ;}
6. hc = 0; $distance_{between}$ = 0; m = 0; $MSS_{traversed}$ [0] = $MSS_{traversed}$ [m];
7. repeat steps 1 to 5 ; } }
8. else
9. if (MH_status = = -1) {
   9.1. $MSS_{recovery}$ = MSS_c;
   9.2. recovery (); }
10. recovery () {
    10.1. for (i = 0; i < $distance_{between}$; i ++) {
    10.2. transfer content of $MSS_{traversed}$ [i $MSS_{traversed}$ [$distance_{between}$] ;
11. failed MH recovers in $MSS_{recovery}$;}
12. else
13. if (MH_status = = 0)
    13.1. save m_chkpt;

V.A Correctness Proof

Theorem 1: Proposed work ensures information recovery of failed MH with minimum cost.

Proof: As described in algorithm and shown in fig. 1 recovery of information of failed MH is restricted to maximum of h_T or d_T number of MSSs.

Let, h_T or d_T = 4, average information transfer cost between MSSs = 1 unit.

MH_i traverses 11 MSSs and fails in 11^{th} MSS.

In normal case, information recovery is required from 10 previously traversed MSSs.

Hence, information recovery cost = 10 unit.

In our scheme, information of a MH scattered in MSSs are forwarded to every (h_T + 1 $)_{th}$ or (d_T + 1$)_{th}$ MSS. If such transfer is done n times before MH fails, n * h_T + k = m, m = no. of MSSs traversed, k implies number of MSSs from which information recovery is to be done. Here, k = 1.

Hence, information recovery cost = 1 unit.

This observation proofs above theorem.

Here m= 11, h_T = 4.

Hence n = 2 before MH fails. Thus k = 1.

Theorem 2: Proposed work is non-blocking.

Proof: In Each MSS and MH a dedicated process runs as a background process to handle transfer of m_checkpoints when Genetic Algorithm count or $distance_{between}$ exceed corresponding threshold value.

V. B. Working Example

MHs moves randomly as shown in fig. 1. If Genetic Algorithmoccurs MH saves m_chkpt. If hc>hT checkpoint data of MH is forwarded similarly as case 1. If an MH fails, it must recover from latest saved checkpoint. Fig.1 and Fig.2 depicts all the cases discussed above. Let, h_T =4.

MH moving in combination movement pattern, recovery info. Transferred if h_c between two MSSs exceeds h_T MH moving in intercell movement pattern, recovery information transferred if Genetic Algorithm count of an MH exceeds Genetic Algorithm threshold value

MH moving in intracell movement pattern, if an MH fails recovery MSS will be its current MSS.

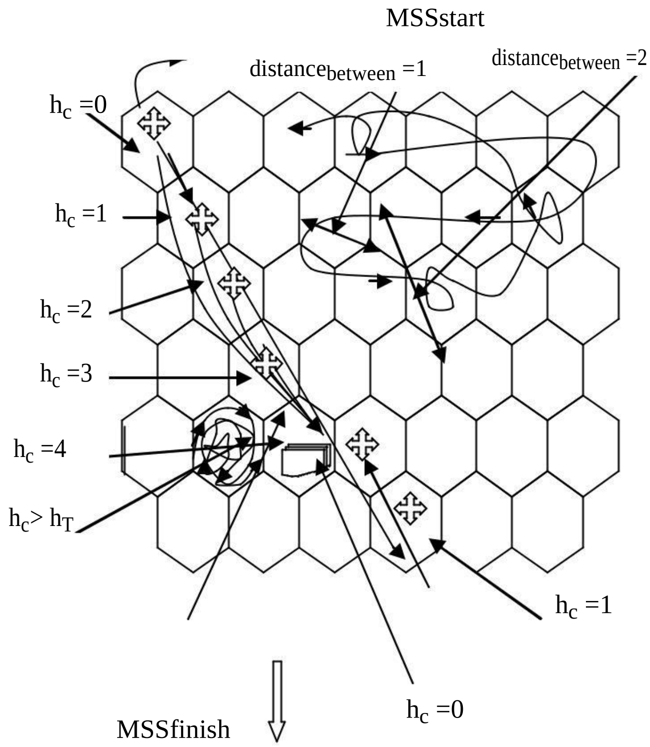

Fig. 1. Movement of MH's

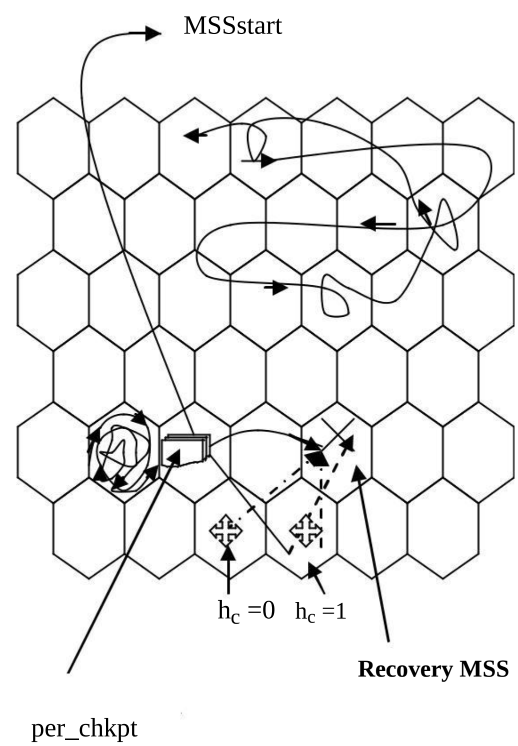

Fig. 2. m_checkpoint transfer

VI. Performance Analysis

Our proposed recovery scheme works on a Wireless Sensor Network consisting of static nodes (MSS) and mobile nodes (MH). MSSs are connected among themselves through wired network and MHs are connected through wireless network to MSSs. MHs move randomly in any direction. MHs save migration checkpoint per handoff. Failure rate follows poisson distribution. Each MH keeps a Genetic Algorithm count value. During the time by which Genetic Algorithm count reaches Genetic Algorithm threshold value is considered to be a permanent checkpoint interval. For performance measurement migration checkpoint cost, permanent checkpoint cost and its transfer cost are considered as parts of recovery cost.

Total failure free operation cost during ith interval (C_{ffo_i})

$$= \int_{hc=0}^{hc=hT} Cffo\_i = h_T * Cmg\_ch + h_T * Cmg\_ch\_transfer + Cper\_ch$$

Cmg_ch = cost of saving a migration checkpoint

Cmg_ch_transfer = cost of transferring a migration checkpoint over wired network

Cper_ch = cost of saving permanent checkpoint

If an MH fails, its current MSS acts as recovery MSS. Sends recovery message to the MSSs in the MSStraversed list during last interval. MSSstart forwards permanent checkpoint and other MSSs sends m_chkpts to the recovery MSS.

VI. A Recovery Cost

Proposed scheme:

Max_recovery cost at i_{th} interval

$= h_T * Cmg\_ch\_transfer + C_{per\_ch\_transfer}$ of (i-1)th interval

$= K_1 + K_2 =$ constant

Region based recovery scheme:

Max_recovery cost at i_{th} interval

= no. of MSSs traversed * Cmg_ch_transfer + $C_{per\_ch\_transfer}$ of (i-1)th interval

= no. of MSSs traversed * Cmg_ch_transfer + k

hence, Max_recovery cost at i_{th} interval ∞ no. of MSSs traversed

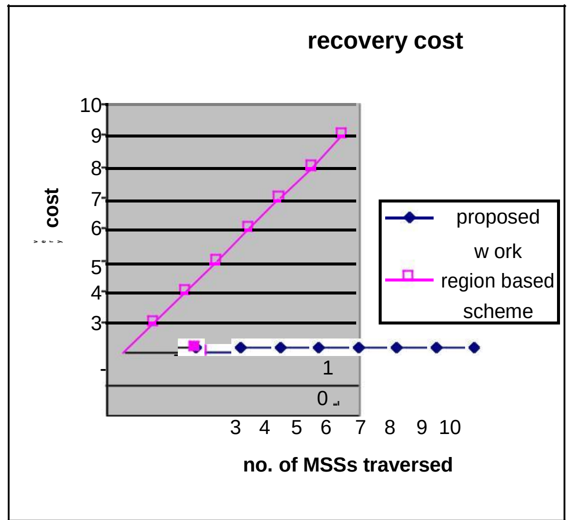

Figure 3: Maximum recovery cost is constant as permanent checkpoint transfer cost and migration checkpoint transfer cost are always almost constant.

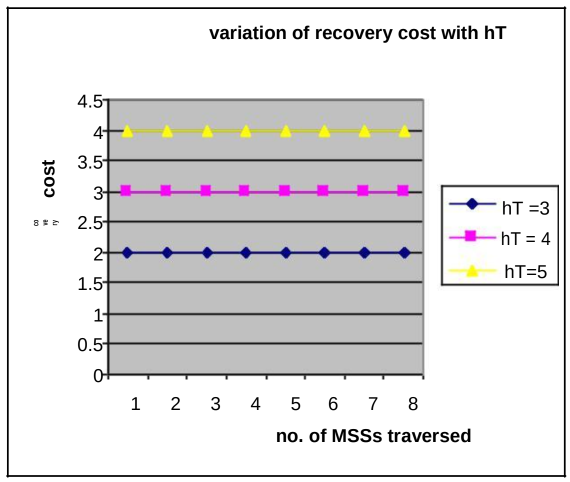

Figure 4: In figure 3 recovery cost varies for varying h_T. For higher h_T, permanent checkpoint transfer cost and migration checkpoint transfer cost increases.

VI. B Comparison of proposed work with existing works

Number of communication messages (region based):

Recovery MSS to RM+ RM to recovery MSS = 1+1+1 = 3 (minimun)

Definition of a Region :

Region 1= 0-1-2-3-4-5-6 , dist = 1, no. of MSSs = 7

Region 2 = 0-1-2-3-4-5-6-7-8-9-10-11-12-13-14-15-16-17-18 , dist = 2, no. of MSSs = 19

If 2 such regions are taken into consideration, total number of MSSs = 14, 38 for dist = 1 and 2 respectively as shown in figure 5.

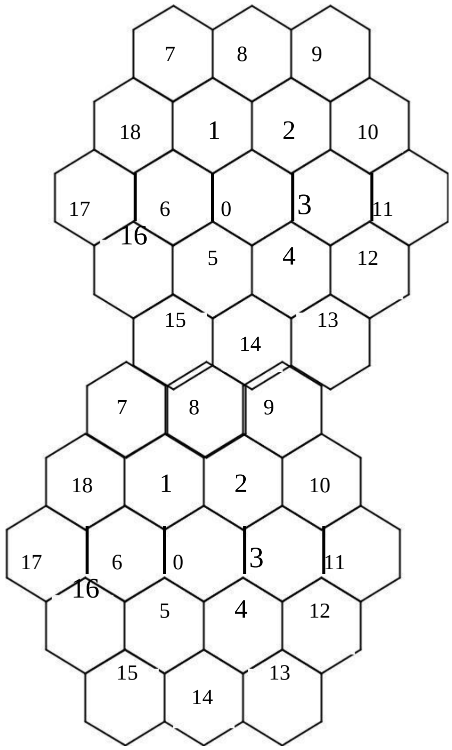

Figure 5: two regions of dist = 2

MH movement is considered in the 2 regions of distance =2. In [3], there are 4 schemes of region based recovery.

Scheme 1: maximum number of communication message required = 4

Scheme 2: maximum number of communication message required = 37 = (m-1)

Scheme 3: maximum number of communication message required = 2

Scheme 4: maximum number of communication message required =36

Hence maximum number of communication message required = 37

Number of communication messages (proposed work) :

$P*h_T + k = m$, [sec. 7], m = no. of MSSs, p = number of times h_T number of m_checkpoints forwarded, k = number of MSSs where recovery information of MH in current region is dispersed.

Hence if MH fails, recovery MSS collects information from k MSSs

Maximum number of communication message required = 2k

If the regions in fig. 3 is considered, then an MH can move across maximum m = 38 MSSs

P*4 + k = 38, if p = 9, k = 2

maximum number of communication message required = 4

Recovery cost: Recovery cost has two components:

i) communication message cost ii) recovery information transfer cost

Proposed work: recovery cost = C_{4k} + k*Cmg_ch_transfer
region based scheme**:** recovery cost =$C_{(m-1)}$ + (m – 1) * Cmg_ch_transfer

Algorithm	Number of Communication messages	Recovery cost (max)
Region based	m-1	C**(m – 1)** + (m – 1) * Cmg_ch_transfer
Proposed	2*k	C**4 k** + k*Cmg_ch_transfer

Table 1**:** comparison of proposed scheme with region based recovery scheme

VI. C Failure free operation cost

Let an MH traverse m number of MSSs without failure. In proposed scheme, recovery information of an MH is proactively transferred as explained in sec.4.1. $P*h_T + k = m$, $P*h_T$ = total number of recovery information transfer. Per transfer cost = 1 unit, total transfer cost = $P*h_T$ unit. Failure free operation cost is also optimized with the m_checkpoint forwarding strategy because information of an MH gets accumulated to its nearer MSSs facilitating execution of a specific problem by a single MH or a group of MHs.

VII. Conclusion

Proposed recovery technique focuses on faster and efficient recovery information dispersed over a number of MSSs due to random movement of MHs. Our work limits the number of MSSs from which recovery information of a failed image to be collected. Our work also reduces number of communication messages, a significant overhead reduction in Wireless Sensor Networks. Recovery cost with failure is optimized. Failure free operation cost is also optimized because the recovery scheme described here works parallel table normal execution of mobile nodes without causing any blocking or delay effect.

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