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Efficient MAC Based on Hybrid TLBO-PSO Optimization for Wireless Body Area Network

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Abstract: This study designs a MAC by using the hybrid TLBO-PSO algorithm for the Wireless Body Area Network (WBAN). The CSMA/CA based MAC computes the delay to transmit the data on channel by sensing the channel along with adding a random delay. The designed MAC uses the basic concept of CSMA/CA to sense the channel but the delay added to transmit the data is the optimized delay computed by the TLBO-PSO algorithm. The algorithm also, uses the low range sensor to reduce the specific absorption rate resulting less bad affect on human body due to sensor radiations. The performance of the algorithm has been compared with existing three state of art techniques, TDMA based MAC, Aloha based MAC, CSMA/CA based MAC optimized by PSO on different WBAN scenarios. The results clearly show the significance of designed technique.

Key words: TDMA, Aloha, CSMA/CA, PSO, TLBO, MAC, WBAN

INTRODUCTION

Wireless Body Area Network (WBAN) is an energizing innovation that guarantees to convey human services to another level of personalization. Scaled down sensors can be worn on the body and they can non-rudely screen a man's physiological state (Abbasi *et al*., 2014; Sarkar *et al*., 2015). Different sensors communicate with a cell phone utilizing remote interfaces framing a WBAN. WBANs empower checking a person's wellbeing consistently in free living conditions where the individual is allowed to lead his/her day by day action. The cell phone in a WBAN is utilized to gather wellbeing information from sensors, store and even incompletely process information locally and transmits the wellbeing information over remote connects to a back-end preparing server (Masud *et al*., 2017). The advancement of BANs ought to take after the regularly expanding improvement in the therapeutic space, its primary goal being to guarantee steady watchful and unavoidable observing of patients at home or at work (Kirbas *et al*., 2013).

In WBAN, wearable frameworks for unending wellbeing checking are a key innovation in helping the progress to more pre-emptive and reasonable human services. They permit observing the demonstrative status of patient and giving input to keep up an ideal wellbeing status and give her/his better human services. From most recent couple of years we are getting assortment of wearable wellbeing observing gadgets, going from basic heartbeat screens, movement screens and holter screen, to advanced and costly implantable sensors. Body zone organize depicts the use of implantable or wearable wellbeing observing gadgets as keen sensors (Hauer *et al*., 2011; Hao *et al*., 2005).

The fundamental motivation behind wearable framework is to nonstop observing of biomechanical and physiological information in their typical activities. The patient's sensor gadgets are associated with controller node and afterward this node is associated with any internet device like PDA for outside correspondence with hospitals or doctors (Annavajjala and Zhang, 2010; Otto *et al*., 2005) (Fig. 1).

Medium Access Control (MAC) conventions assume a vital part in taking care of the previously mentioned issues. For the most part they are assembled into contention based and schedule based MAC conventions. In contention based MAC conventions for example, Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA) conventions, nodes brawl for the channel to transmit information. On the off chance that the channel is occupied, the node concedes its transmission until the point that it ends up transmission or become idle. These conventions are adaptable with no strict time synchronization limitation (Huang and Quek, 2015). Moreover, optimization has been applied to such convention to optimize the performance. The PSO optimization already has been applied by researcher of (Wu and Lin, 2015) which proves its significance in term of performance.

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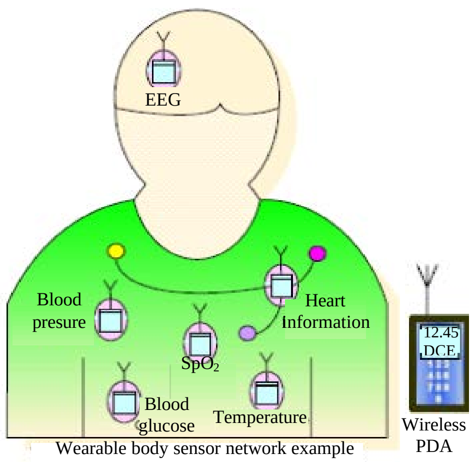

Fig. 1: Wearable body sensor network (Annavajjala and Zhang, 2010)

Nonetheless, they bring about huge convention overhead. In schedule based conventions like TDMA (Time Division Multiple Access) conventions (Fang and Dutkiewicz, 2009), the channel is separated into availabilities of settled or variable span. These spaces are doled out to nodes and every node transmits amid its opening period. These conventions are energy rationing conventions. The duty cycle of radio is lessened and there is no conflict, overhearing and idle listening issues. These conventions, notwithstanding, require regular synchronization. The Aloha convention transmits the signal after sensing the channel. The convention senses the channel and when it is free transmit the signal immediately (Benedetto *et al*., 2007). The slotted Aloha convention is a modification of Aloha which divides time slits and sense the channel continuously. Whenever, the channel is free then it transmits the data in next time slit (Hussain *et al*., 2011).

MATERIALS AND METHODS

This study describes the Particle Swarm Optimization (PSO), Teacher Learning Based Optimization (TLBO) along with hybrid PSO-TLBO algorithm. Moreover, the hybrid PSO-TLBO based algorithm for WBAN is also, given in this study.

PSO: In the particle swarm optimization, the position of the particle gives the optimized solution for the given problem. The algorithm initiates with candidate solutions that consist random position assigned to particles for initiations. The position of the particle is according to, the velocity which is updated by using Eq. 1:

$$V_p^{t+1} = \alpha V_p^t + \sigma_1 * \text{rand} * \left(\text{pbest}_p^t - cp_p^t\right) + \sigma_2 * \text{rand} * \left(\text{gbest}^t - cp_p^t\right) \quad (1)$$

Here, current position of pth particle at time t is given by CP^t_p, global best position among all particle is given by gbest. The previous best position of the particle is used by using pbest^t_p. Rand gives the random number between 0 and 1. σ, σ_1, σ_2 are the constants. The position get updated with the updated velocity by using Eq. 1 is given by Eq. 2:

$$CP_p^{t+1} = CP_p^t + V_p^{t+1} \quad (2)$$

This process is repeated until stopping criteria achieved to find the optimized solution (Tripathi *et al*., 2007).

TLBO: Teacher leaning based optimization used the concept that learner of every class learns due to the teacher or the other learners within the class. This algorithm is efficient and needs no parameter tuning for the optimized performance. This algorithm works in two phases one is teacher phase and other is learner’s phase (Rao *et al*., 2011).

In the teacher phase, the leaner with the best objective value, i.e., best leaner is selected as the teacher. The value of each leaner is updated corresponding to the teacher by using Eq. 3:

$$L_{j\_new} = L_j + \text{rand} * (L_{teacher} - TF * L_M) \quad (3)$$

Here, L_{j_new}, L_j are new and the existing leaning factor of jth learner while $L_{teacher}$, L_M are best and mean learning factors. TF is the teaching factor whose value varies from 1-2 given by Eq. 4:

$$TF = 1 + \text{rand} \quad (4)$$

The new solution is accepted only if $F(L_{j\_new})<F(L_j)$ for a minimization problem and $(L_{j\_new})<F(L_j)$ for a maximization problem. The updated value is passed to the second phase of algorithm, i.e., learner’s phase. In the learner’s phase knowledge is updated due to another learner in the search space. It is given by Eq. 5:

$$L_{new\_j} = \begin{cases} L_j + \text{rand} * (L_j - L_i) \,|\, F(L_j) < F(L_i) \\ L_j + \text{rand} * (L_i - L_j) \,|\, \text{else} \end{cases} \quad (5)$$

The updated value of jth due to the ith learner is derived using Eq. 5 is accepted only if it is better than the existing value. These two phases of process are repeated until stopping criteria achieved (Zou *et al*., 2013, 2015).

PSO-TLBO: The PSO-TLBO is a hybrid algorithm designed to remove the drawback of the individual PSO as well as TLBO algorithm. The PSO algorithm is an effective algorithm but the main limitation of this algorithm is slow convergence rate and the premature convergence. While the TLBO performs well only for few functions, basically this algorithm lacks in diversity as well as in distribution especially for the non-convex functions. In this hybrid algorithm TLBO is incorporated into the PSO algorithm. It means the task to search the global optima is of PSO algorithm while TLBO algorithm looks for the extended search space also, push the solutions to fast the process. The process of pushing solution for global optima is of teacher phase while wide search is done using learner's phase. Moreover, the hybrid algorithm uses the external archive to store the dominating solution. It is done by deleting the non-dominating solution and truncating the solution larger than maximum length. The truncation is done by circular crowding sorting which eliminates the crowded solution from the external archive. The polynomial mutation is applied in the PSO-TLBO algorithm to remove the uncertainty due to mutation (Cheng *et al*., 2016). The whole process can be easily understood by following Algorithm 1:

Algorithm 1; PSO-TLBO algorithm:

PSO-TLBO(iter_max, E_A,E_A_, Liter_interval, pop_size)

/* Here E_A is the external archive with E_A_S as the size of the external archive. The maximum number of iterations for which process can be repeated is iter_max with inter_interval as interval gap between iteration. The pop_size is the population size for the iteration. */

1. Initiate Population as pop
2. E_A = non_dominated(pop)
3. Iter=1
4. While iter< = max_iter
   a. For each particle say x_{pop} in pop
      If iter%iter_interval>0
      i. Adjust parameters of PSO
      ii. $gbest^{iter} = global(E\_A)$
      iii. $V_{pop}^{iter+1} = \alpha V_{pop}^{iter} + \sigma_1 * rand * \left(pbest_{pop}^{iter} - x_{pop}^{iter}\right) + \sigma_2 * rand * \left(gbest^{iter} - cp_{pop}^{iter}\right)$
      iv. $x_{pop}^{iter+1} = x_{pop}^{iter} + V_{pop}^{iter+1}$
      Else
      v. TF = 1+rand
      vi. $L_{teacher}$=best(E_A)
      vii. $L_M = \frac{\sum_{p \in pop} L_p^{iter}}{pop}$
      viii. $x_{pop\_new}^{iter+1} = x_{pop}^{iter} + rand * (L_{teacher} - TF * L_M)$
      ix. $V_{pop}^{iter+1} = x_{pop\_new}^{iter+1} - x_{pop}^{iter+1}$
      End if
   End for
   b. Apply polynomial mutation on V_{pop}
   c. Compute pbest on pop
   d. $E\_A = non\_dominated(E\_A \cup pop)$
   e. If size(E_A)> E_A_L then Apply CCS to truncate E_A end if
   f. Iter=iter+1
   End while
5. Return E_A

The E_A, i.e., external archive list contains the solution. The performance of this hybrid PSO-TLBO algorithm is better than the PSO as well as TLBO algorithm (Cheng *et al*., 2016). This algorithm has been modified to implement on wireless body area network discussed in next studys.

Hybrid PSO-TLBO algorithm for wireless body area network: The hybrid PSO-TLBO algorithm has been modified to be implemented on the wireless body area network. The number of nodes in the network is the population size of the network. The objective is to sense the maximum activity of the body with the minimum number of sensor nodes on priority basis. Human body absorbs radiations emitted by the sensors placed near, over or inside the body. These radiations may affect the health of a person badly if the radiations are not emitted in a controlled manner. The parameter to control the radiations is specific absorption rate which is to be minimized by the objective function. Moreover, the duty cycle of every node plays an important role as the nodes have limited battery power. The target is to extend the lifetime of the sensor node which is done by minimizing the duty cycle of a node. The objective function computes the time to transmit the signal, i.e., data from sensor node to the controller node through channel given by Eq. 6:

$$T\_T = \alpha_1 * SAR + \alpha_2 * r * t\_delay \quad (6)$$

Here T_T is the transmission time denoting the delay to transmit the data , SAR is the specific absorption rate which is constant for a network, i.e., SAR is evaluated at the network setup. r is a variable having random value in between 0 and 1. α_1, α_2 are constants such that $\alpha_1+\alpha_2 = 1$ and t_delay is calculated by Eq. 7:

$$t\_delay = \begin{cases} delay <= th\_min?delay: \\ \begin{cases} delay + (c\_t\text{-}l\_c\_t) | colloision = true \\ delay - (c\_t\text{-}l\_c\_t) | otherwise \end{cases} \end{cases} \quad (7)$$

Here, current delay, i.e., transmission delay along with propagation delay is represented by the delay which is modified only if the delay is higher than the minimum threshold delay given by th_min (determined on benchmark basis based on network) to t_delay on the basis whether collision occur or not. The c_t denotes the current time and l_c_t denotes the last collision time. The delay is increased if the collision occurs otherwise the delay decreased. This objective function evaluates the transmission time, lower the T_T better the result.

The hybrid PSO-TLBO algorithm computes the non-dominated solutions based on the time to transfer the data from the sensor node to the controller node to PDA without collision while initially this list is prepared on the basis of priority of nodes. Moreover, the beacon interval is used as the iteration interval. The nodes sense the body activity and transfer it to the controller node in such a way that it consumes minimum amount of energy and no emergency message got missed out. The process can be easily understood by following Algorithm 2:

Algorithm 2; WBAN network algorithm:

HPTA_WBAN(N,B_I,C_N_S,C_N_S_L,C_N)

/*A WBAN network with N nodes and C_N as the controller node is given. The controller node is an intelligent node with external storage denoted as C_N_S. The capacity of this external storage is C_N_S_L. The B_I is the beacon interval which is the average time to send data from a sensor node to the controller node.*/

1. Initiate network with N nodes with different priority based on their function
2. E_A=non_dominated(N);Here non_dominated list is prepared based on priority of nodes
3. T_N= E_A(1);
4. While T_N~=C_N
   a. Until data Transmitted from T_N
   repeat

If c_t%B_I>0

i. Adjust parameters of PSO

ii. $gbest^{c\_t}$=global(E_A)

iii. $$V_N^{n\_c\_t} = \alpha V_N^{c\_t} + \sigma_1 * rand * \left(pbest_N^{c\_t} - T\_N_N^{c\_t}\right) + \sigma_2 * rand * \left(gbest^{c\_t} - cp_N^{c\_t}\right)$$

iv. $$T\_N_N^{n\_c\_t} = T\_N_N^{c\_t} + V_N^{n\_c\_t}$$

Else

v. $$TF = 1 + rand$$

vi. $L_{teacher}$=best(E_A)

vii. $$L_M = \frac{\sum_{p \in N} L_p^{c\_t}}{N}$$

viii. $$T\_N_N^{n\_c\_t} = x_N^{c\_t} + rand * (L_{teacher} - TF * L_M)$$

ix. $$V_N^{n\_c\_t} = x_N^{n\_c\_t} - x_N^{n\_c\_t}$$

End if

End

b. Apply polynomial mutation on V_N
c. Compute pbest on pop
d. E_A = non_dominated (E_A∪N)
e. If size(E_A)> E_A_L then Apply CCS to truncate E_A end if
f. Update T_N

End While

5. Exit

The algorithm transmits the data from sensor nodes to the controller node with minimum collision and delay. The above algorithm uses the optimization to optimize the delay to transmit the data from a sensor node to the channel. This optimization reduces the delay and also avoids the collision. The implementation and analysis of the algorithm has been discussed in next study.

RESULTS AND DISCUSSION

The algorithm discussed in the previous study has been implemented using the network simulator. The algorithm basically works on the MAC to avoid the collision and transmit the data efficiently, i.e. with minimum delay to the controller node which further transfers the data to the PDA and to medical server. The performance of the algorithm has been compared with different state of art algorithms, i.e., TDMA based MAC, Aloha based MAC and CSMA/CA based MAC with PSO for optimization of route already discussed in previous of study. The comparison has been done by using the loss ratio (total number of packet lost in the network), throughput (output in the given span of time), the delay in transmitting the data and the average amount of available energy as the parameter. The analysis has been done on WBAN scenario within a small area of $5*4m^2$. The different scenario considered within the given area contains 3, 5, 7, 8, 9 nodes respectively. One node is the controller node which communicates with the PDA, i.e., mobile node of the network. Apart from PDA and controller node, different sensor nodes have distinct functionality, i.e., to measure the, ECG, blood pressure, EEG, glucose level and toxin level. Moreover, the transmission range of the sensor node is just the circle with the radius of 4 cm. This small range of sensor node with less number of nodes is used to manage the SAR, i.e., specific absorption rate as higher transmission range affect the health of person badly. The performance analysis has been shown in Fig. 2-5.

Figure 2 compares the loss ratio of the proposed, i.e., CSMA/CA based MAC optimized by hybrid PSO-TLBO algorithm with the existing CSMA/CA based MAC optimized by PSO algorithm and Aloha, TDMA based MAC The loss ratio of the proposed algorithm is lower than the other stated state of art algorithms. This is due to the collision avoidance by not sending the data immediately as the channel is sensed free. The transmitter node waits for an optimized delay even if channel is free. This reduces the collision resulting less loss of packets.

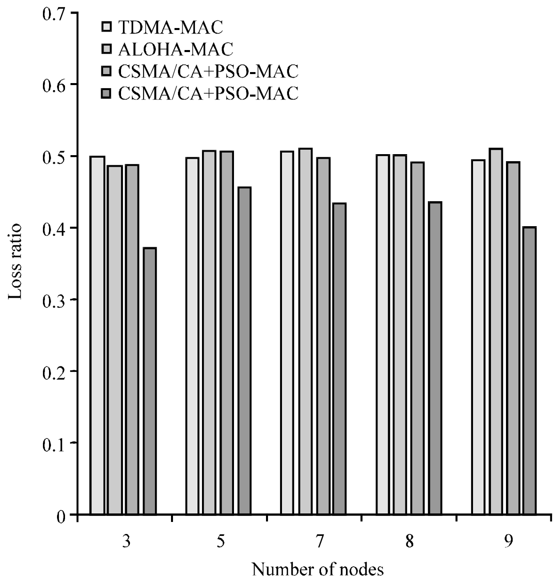

Fig. 2: Analysis of loss ratio

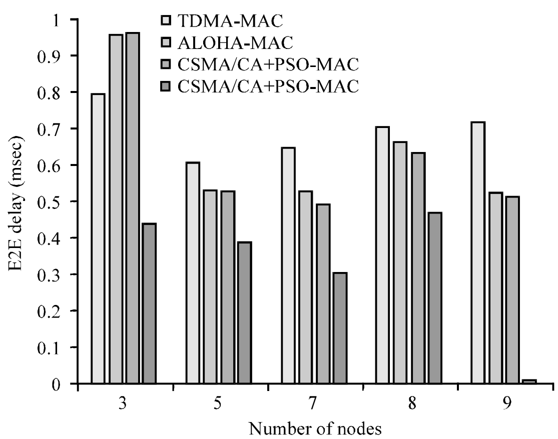

Fig. 3: Analysis of end to end delay

The end to end delay to transfer the packet from a sensor node to the controller node of the HPTA_WBAN (proposed) algorithm is compared with existing state of art algorithms in Fig. 3. The delay has been reduced significantly by introducing the hybrid PSO-TLBO based optimization. The optimization algorithm has selected an optimized delay to reduce the end to end delay of the data transfer from the sensor node to the controller node.

Figure 2 compares the average amount of remaining energy of the proposed, i.e., CSMA/CA based MAC optimized by hybrid PSO-TLBO algorithm with the existing CSMA/CA based MAC optimized by PSO algorithm and Aloha, TDMA based MAC. The average amount of remaining energy is computed by adding

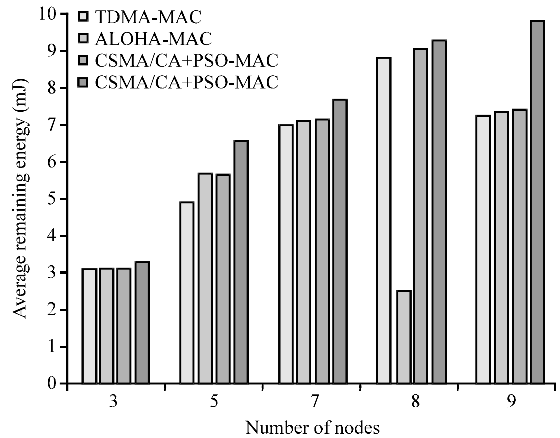

Fig. 4: Analysis of remaining energy

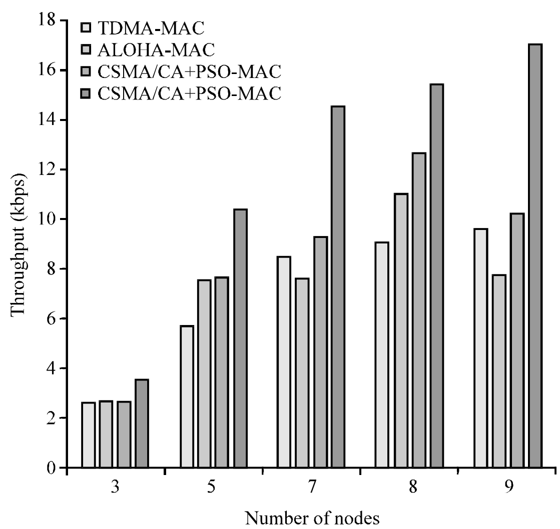

Fig. 5: Analysis of throughput

up remaining energy of all nodes then dividing it by number of nodes. The average remaining energy of the proposed algorithm is higher than the other mentioned state of art algorithms. This is due to the transmission of data in an optimized manner with less delay.

The analysis of throughput for the proposed and existing state of art algorithms has been done in the Fig. 5. The higher throughput of the proposed algorithm as compared to TDMA, Aloha based MAC and CSMA/CA+PSO based MAC prove the significance of the algorithm. This is due to reduced delay to transfer the data from the sensor node to the controller node.

CONCLUSION

This study designs HPTA_WBAN algorithm which optimize the delay to transmit the data during CSMA/CA

MAC technique by using hybrid PSO_TLBO based optimization. The algorithm has been compared with TDMA, Aloha based MAC along with CSMA/CA based MAC optimized by PSO. The analysis has been done on different WBAN scenarios having different number of sensor nodes by using throughput, delay, remaining energy and loss ratio. The decrement in the loss ratio and delay along with enhance in throughput and remaining energy of the given technique as compared to existing state of art technique proves its significance.

SUGGESTION

In future, this optimization can be applied to routing along with MAC to enhance the performance.

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