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Swarm and Fuzzy Based Cooperative Caching Framework to Optimize Energy Consumption Over Multimedia Wireless Sensor Networks

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Abstract Rapid technological advancement has spurred an impressive growth of industrial application for Multimedia Wireless Sensor networks. The entire sensor nodes are operated with the help of battery. An approach towards evolving low energy networking has been a great challenge, especially a battery which is worked storage and the nodes that are forwarded. More energy is consumed during data transmission and query processing. The possible solution is to minimize energy consumption by the use of cooperative caching method. In this research work, a Mobility with Clustering based Energy Efficient Cooperative Caching (MCE2C2) method is proposed. In this framework, the reservation node selection is performed using fuzzy interference system. The data transfer from the intermediate node and reservation node are performed by swarm intelligence based routing. When the sensor node accepts the data, the caching decision is evaluated by two parameters such as information present index and content drop time. The cache performance is improved by using the clustering mechanism and integrating the cache consistency and the cache replacement Push–Pull and Energy efficient Cache Replacement algorithms are used respectively. By using MATLAB and NS2 simulator, the performance of MCE2C2 is evaluated and the results are compared with existing approaches. As a result of this the sensor node energy is improved.

Keywords Multimedia wireless sensor networks · Energy · Clustering · Cooperative caching · Swarm intelligence · Fuzzy logic

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List of symbols

M_{oj} (i)	Mobility metric
RSS	Residual signal strength
P_{rx}	Reception power
P_{tx}	Transmission power
AB	Available bandwidth
Q_d	Number of allocation slots in one frame
Q_t	Total slots in the sub-frame
t_f	Duration of the frame
β	Number of bits transmitted in downlink slots
N_i	Sensor node
N_j	Neighbor node
d_{ij}	Distance among N_i and N_j
η	Wavelength
α	Transmitter gain
β	Receiver gain
ETT	Expected transmission time
z	Average size of a packet
BW	Current link bandwidth
ETX	Expected transmission count metric
Pr_{tx}	Successful packet delivery probability in forward direction
Pr_{rx}	Successful acknowledgment packet reception probability
ET	Expected time to stay
BL	Battery life
D	Distance from the node
LQ	Link quality
f_i	Fuzzy rules
ψ (f_i)	Membership function
a $(N_i$, $S)$	Pheromone value
b $(Ni$, $So)$	Heuristic value related to bandwidth
RT (N_i)	Routing table for N_i
ζ	Parameters to control the relative weight of the pheromone value
σ	Parameters to control the relative weight of the heuristic value
X_{us} (R)	Total number of Ni visited by FANT
R	Number of iteration
λi	Information presence index
k	Time step
C_{i1} $(N_i$, $k)$	Source counter
ε	New copies of information
H_1	Number of hops covered by the new copies of data
C_{i2} $(N_i$, $k)$	Movement counter
T_{dmax}	Maximum cache drop time
T_{di} $(N_i$, $s)$	Cache drop time
i	Data
T_{pmax}	Maximum cache stability time
u	Time-out value

1 Introduction

The Multimedia wireless sensor networks (MWSNs) that are present in the modern eras is a high growth. In spite there are a large number of technologies that are present to support the sensor nodes [1, 2]. These sensor nodes are present to sense and to detention the multimedia content such as that of the audio, video and image. These networks are deployed in various applications like surveillance multimedia camera monitoring, environmental observation for landfill gates, waste water management, query processing, pollution effect, traffic monitoring, temperature control monitoring, object movement monitoring, light intensity monitoring, etc. at a Low cost, low power sensor nodes [3]. Due to a large number of a quarry processing and various types of applications these multimedia sensor nodes consume more energy.

Multimedia sensor nodes use battery power to forward packets of intermediate nodes to the desired recipients. Also, there is this sensor node that acts as an intermediate between the forwarding node and the other present node in order to forward the data in the sensor network. The service provides in turn are responsible for a high power consumption leading to a high cost. The absence of the forwarding node leads to no multimedia wireless sensor networks. For instance, a node with a full battery powers its forwards data onto its neighbors. A node with a low battery power might limit its activities in communication excepting for emergency and high priority messages. Therefore, one of the main design goals of MWSNs is to prolong the lifetime of network and to prevent connectivity degradation. For this purpose employing a cooperating cache management technique has been proposed.

Caching relevant sensor data onto the sink is an effective tool for improving the performance in multimedia wireless sensor networks. In [4] Data access requires sensing coverage and the properties of communication connectivity. Increased sensing coverage area allows retrieving past data that reside in the cache [5, 6]. Hence the query processing performance can be improved by caching frequently requested data. In [7] data caching techniques of traditional wireless networks can be extended to Wireless Sensor Networks. The main issues in MWSNs are data availability and consistency due to the absence of permanent infrastructure. Especially, integration of cache consistency and cache replacement are the exacerbated in MWSNs. Motivated by the unique requirement of multimedia data onto MWSN, the Mobility based Energy Efficient Cooperative Caching (MCE2C2) technique is proposed. Mobility in MWSN can be made possible with the help of the mobile base station along with the forwarding of data with the help of the mobile entity to another base station.

The proposed method is implemented in four stages. First, reservation node is selected using fuzzy input parameters like Expected Time to Stay (ET), Battery Life (BL), Bandwidth (AB), and Distance from the Senor Node (D), link Quality (LQ). Second, the data forwarding from intermediate node to reservation nodes is performed using Ant Colony Optimization Routing (ACO). ACO is based on Swarm Intelligence and it is a better method of multimedia wireless sensor networks. Third, mobility with cluster based communication energy model (MCE2C2) is proposed. In this energy model, there exists a cluster head (CH) which controls and monitors the cluster. Overall the sensor filed is seen as an equal sized grid known as cluster. The clustering techniques clearly sets a rule that the communication with the mobility node is done only by the cluster head also there the other members in the cluster are only allowed to listen to what is happening in the network. Because of such a thing, there is large amount of power is getting saved in the nodes that are present since the communication is only done by the cluster head rather than the nodes present in the cluster with the mobile entity. In the final stage, cache consistency and cache replacement of optimizing the sensor node energy with low network latency are integrated [8].

The forthcoming research article is prepared in the succeeding method. The related work of this article is described in Sect. 2. The detailed methods and materials are presented and explained in Sect. 3. The simulation (MATLAB and NS2) experimental outcomes are demonstrated in Sect. 4, followed by a comprehensive inference in the Sect. 5.

2 Related Works

In [2] the authors propose a supportive storing system E3C2 for supportive well-organized data collection and processing in WMSNs. By the help of this system, the multimedia data can be shared thus reducing the query latency and energy consumption of the nodes. In this proposed method was compare with NICoCa and C3S strategies.

In [9, 10] the authors have proposed that the Caching techniques reduce the data access delay as the local cache serves some data access requests ensuring that there is proper transmission even were there links are not present continuously. The Cooperative storing permits allotment and coordination of cached information amongst the various nodes present thereby reducing the bandwidth and power consumption if ad-hoc mobile nodes have similar tasks and share common interests. Surely, mobile nodes are required by this cache in order to synchronize with every other.

In [11] the author proposes and compares NICoCa, which is a node importance (NI) cooperative caching method. By including the importance of the node in the WMSN along with the residue energy at each sensor node, NICoCa can drag the lifetime of the network and even reduce the latency. Though, solitary enchanting the qualities of multimedia item such as the timestamp and data size, it will be insufficient for cache replacement. This is since the multimedia article having a larger size is given the most priority as the replacement of the candidate victim. Therefore, the importance of data item in terms of content is also equally important while making the cache replacement decisions. There is a consumption of energy by the node importance (NI) this reduces the sensor network's lifetime.

In [12] the authors have proposed a dispersed classical for hoarding Web facility technique signs and call answers to MANET by introducing three main contributions to caching in mobile ad hoc networks. First, a complete system comprising of the desirable organization and procedures in order to improve the Web-service-generated information obtain ability in MANETs, and to decrease the regular interruption to access data by the mobile procedures was described. Second, it delivers an intricate examination of the regular appeal delay, the produced traffic, and the load into the assigned special roles nodes was provided [13]. Third, the ns2 network simulator experimentally evaluated system in order to authenticate that the analytical model of the system is correct and also if gives the measures for dynamics in the MANET-like device mobility and traffic collisions. The roads acts like a "free riders" without the scheme by taking on PC or CN roles.

In [14, 15] the authors have proposed that the Probabilistic Delta Consistency (PDC), a general steadiness classic integrates the current reliability representations' flexibility, covering them as special cases. Flexible Combination of Push and Pull (FCPP) algorithm was also proposed to satisfy user-specified consistency requirements under the PDC model. The analytical model of FCPP derives the balance to minimize the cost of the maintenance and also the specific requirements. Also the traffic cost can be saved up to 50 %. The query delay is reduced up to 40 %, when associated with the extensively used Pull with TTR algorithm.

In [16–23] the hamlet was introduced by the author which is a caching strategy basically for the wireless networks. The nodes of these are made to exchange which is a fully determined scheme. This is done by determining each node with its information store with drop time or which gratified to substitute to make place for those that are arrived newly upon receiving requested information. These decisions rely on the proximity of the node along with its presence. There is no additional overhead that is present in the system where the information is shared. The solving of the probability of information and the overhead traffic that is reduced by Hamlet's caching of information that are not fixed with the nodes that was present nearby. There are few scenarios that are involved, those are vehicular, pedestrian, and memory constrained. However, developed ethics of the Zipf distribution exponent leads to further unstable query rates, with actual prevalent items and a long tail that never accessed data.

In [24–30] order to support active data access to the ad-hoc network has been developed by the pattern of data caching techniques by considering reminiscence capacity restraint of the nodes present in the network. To regulate nearby ideal cache placements the algorithm that are efficient data caching are exploit reduction in complete access cost which results in saving the communication cost and also helps in energy savings and provides better bandwidth. The performance of the caching algorithms was envisioned by simulations over a wide range of network and application parameters. A distributed implementation is presented relying on an approximation algorithm for the cache placement problematic of numerous information substances under memory restriction and the consequences is the content diversity creation that happens within the nodes neighborhood so that a demanding user is able to find the needed information in nearby places. Though any bound on the excellence of the explanation fashioned by DCA cannot be proved.

In [31] the authors have formulated the Energy-efficient Coordinated cache Replacement Problem (ECORP). They have also designed the cache replacement policy. ECORP-Greedy is a heuristic algorithm that is presented and an ideal explanation for the problem which is known as the ECORPOPT is presented. The policies that have been proposed can expressively lessen the consumption of the energy and also reduce the latency which when associated to additional replacement policies is not possible. However there occurs impact in the node density and cache size.

3 Methodology

In this section, the swarm and fuzzy based cooperative caching (MCE2C2) frame is presented. The proposed architecture having all the elements is shown in Fig. 1. The Proposed cooperating caching method is supported by six important features as detailed below.

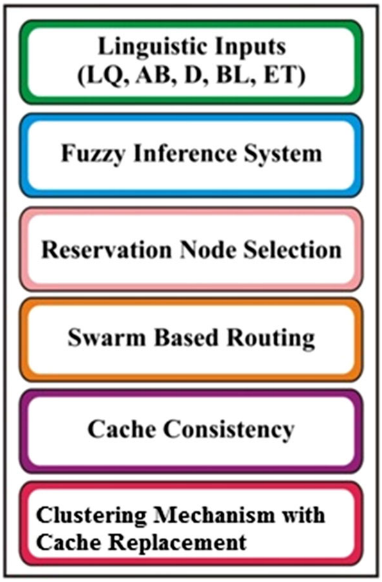
3.1 Estimation of Linguistic Inputs

Fuzzy inference engine [1] takes five linguistic parameters as follows.

3.1.1 Expected Time to Stay (ET)

The expected time to stay is assessed created on the sensor node mobility. The mobility between the two nodes can be estimated from the ratio of RSS obtained amid the packet transmissions between two consecutive nodes that are present from a neighbor node. Thus the mobility metric Mo_j (i) of the node j through i is computed using the following formula.

Fig. 1 A proposed architecture



$$\mathrm{Mo_j(i)} = 10\ \log \frac{RSS^{new}_{i\to j}}{RSS^{old}_{i\to j}} \tag{1}$$

when the estimated mobility value is more, the ET is less and vice versa.

3.1.2 Battery Life (BL)

The battery life is the ratio of power that has been received at the node which is represented by P_{rx} to that of the P_{tx} that is the power that is transmitted by the neighbor node.

3.1.3 Available Bandwidth (AB)

The bandwidth that is available is calculated using Eq. (2)

$$\mathrm{AB} = (1 - Q_d/Q_t)\ \beta\ Q_t/t_f \tag{2}$$

where, Q_d = one frame having the number of allocation slots, Q_t = total number of slots present in the sub-frame, t_f = duration of the frame, β = number of bits transmitted in downlink slots.

3.1.4 Distance from the Node (D)

The distance that is represented by the d_{ij} between a receiver node that is represented by N_j and the sender node represented by N_i. This can be assessed with the help of the free space propagation model. For the transmission and reception, the wavelength is utilized.

The following equation defines the Free-space propagation model

$$P_{rx} = P_{tx} \times \left(\frac{\eta}{4\pi d_{ij}}\right)^2 \times \alpha \times \beta \tag{3}$$

where P_{rx} = reception power, P_{tx} = transmission power, η = wavelength, α = transmitter gain, β = receiver gain.

3.1.5 Link Quality (LQ)

Expected transmission time (ETT) is used to measure the LQ. The expected time to successfully transmit a data packet at the MAC layer as illustrated in Eq. 4 is defined for the expected transmission time (ETT) in a single link. By summing all ETT values the ETT route metric can be calculated for an individual links. This is done by Eq. 4.

$$\mathrm{ETT} = \mathrm{ETX} \times (\mathrm{z/BW}) \tag{4}$$

where z indicates the average size of a given packet, BW indicates the existing link bandwidth, ET indicates the Expected transmission count metric, and this in turn is a metric that measures of link and path quality. The equation representing it is as follows.

$$\mathrm{ETX} = \frac{1}{(\mathrm{Pr}_{tx} \times \mathrm{Pr}_{rx})} \tag{5}$$

where Pr_{tx} = successful packet delivery probability in forward direction, Pr_{rx} = successful acknowledgment packet reception probability.

3.2 Fuzzy Rule Based Reservation Node Selection

The next section presented selecting reservation nodes, when the nodes are entering in the sensor network; it is examined whether it acts as caching a node (CN) or reservation node (RN). The function of reservation nodes is to store the queries presented by the requesting nodes. Caching node stores the response message to the queries. The reservation and cache node detection is achieved by means of fuzzy logic. The node parameters such as predictable time to stay, battery life, bandwidth, and distance from the node and link quality are considered as inputs parameters. In order to get a fuzzy decision rule, the parameters that are given are fuzzified. Also depending on the result of the rules that were applied, this includes combines scores, the RN is selected.

Fuzzy linguistic descriptions are formal representations of system made through fuzzy IF–THEN rules. To establish the fuzzy rule based on the inference is described as follows.

- *Fuzzification* The fuzzication adapts brittle efforts into a verbal variable using the membership function stored in fuzzy knowledge.
- *Rule Evaluation* Application of fuzzy rules.
- *Aggregation of the rule outputs* Combined all outputs.
- *Defuzzification* Actual results.

The fuzzy inference system model is illustrated in Fig. 2.

3.2.1 Fuzzification

This converts scrip inputs such as expected time to stay (ET), battery life (BL), bandwidth (AB), distance from the node (D) and link quality (LQ) are agreed for a grade to suitable fuzzy sets. The brittle efforts are blend of ET, BL, AB, D, and LQ. Three qualitative possibilities, Maximum, Normal and Minimum for ET, BL, AB, D, and LQ have been selected.

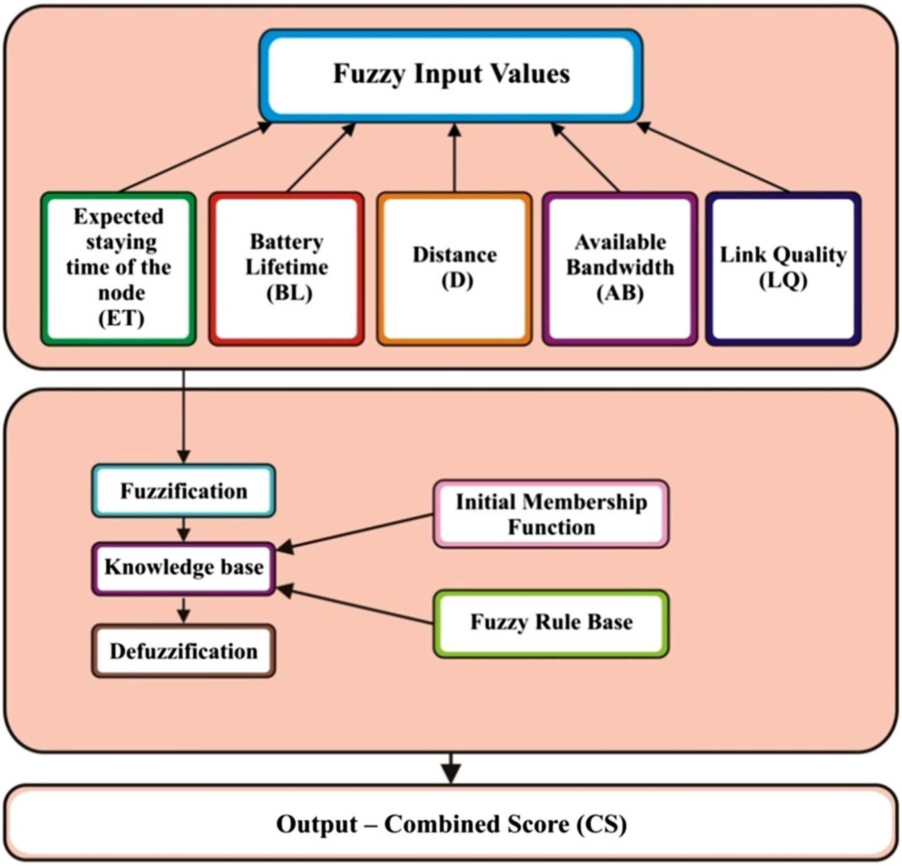


Fig. 2 Fuzzy inference system model

The shape of these functions can be diverse but we will usually work with triangles and trapezoids. Figures 3, 4, 5 and 6 demonstrates the associations function for the verbal contribution and brittle production variables (Fig. 7).

Table 1 demonstrates each possible linguistic term associated with the input attributes of Knowledge base Engineering using fuzzy implication scheme. The productions are interpreted and are computed by fuzzy decision as follows.

For instance

- Rule 14 is considered
- If (ET, BL, AB and LQ = Maximum) & (D = Minimum)
- Then
- CS = Maximum
- The RN is determined by extreme mutual score in the node
- End if

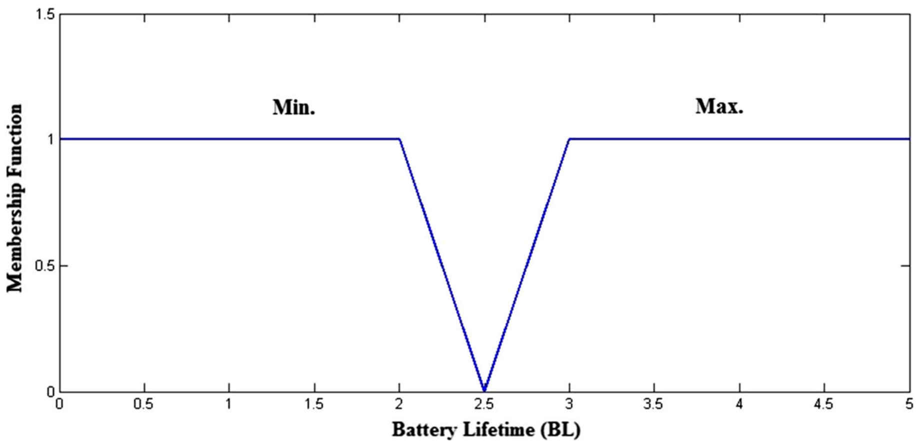


Fig. 3 Membership function of battery lifetime (BL)

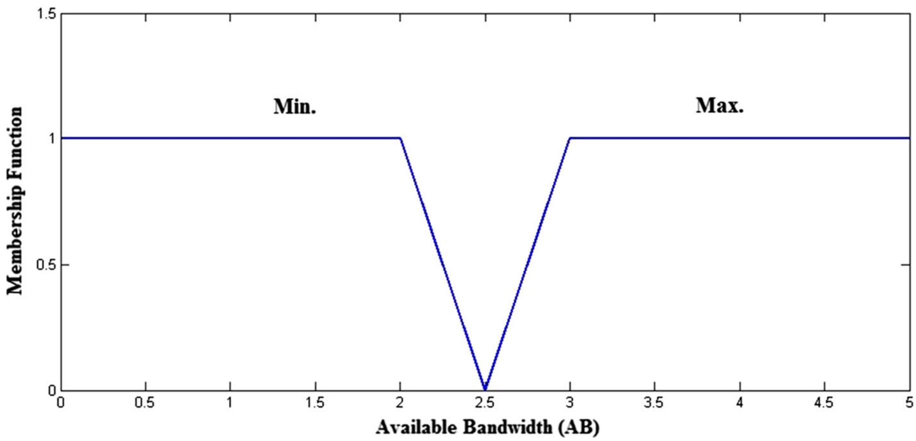


Fig. 4 Membership function of available bandwidth (AB)

3.2.2 Defuzzification Maximum

Defuzzification based on centroid methods, it is an alteration of a fuzzy set into solitary brittle values which is known as defuzzification. It is also the reverse function of fuzzinfication. The formula (6) describes the defuzzifier method.

$$\text{F\_cost} = \left[\sum\nolimits_{allrules} f_i \times \psi(\mathrm{f_i})\right] \Big/ \left[\sum\nolimits_{allrules} \psi(f_i)\right] \tag{6}$$

here, f_i represents the number elements, and Ψ (f_i) is its membership function.

3.3 Swarm Intelligence Based Routing Algorithm

Once the reservation node is selected, the data forwarding takes place from the initial node. The reservation node (RN) is performed by ant colony optimization (ACO). The new two

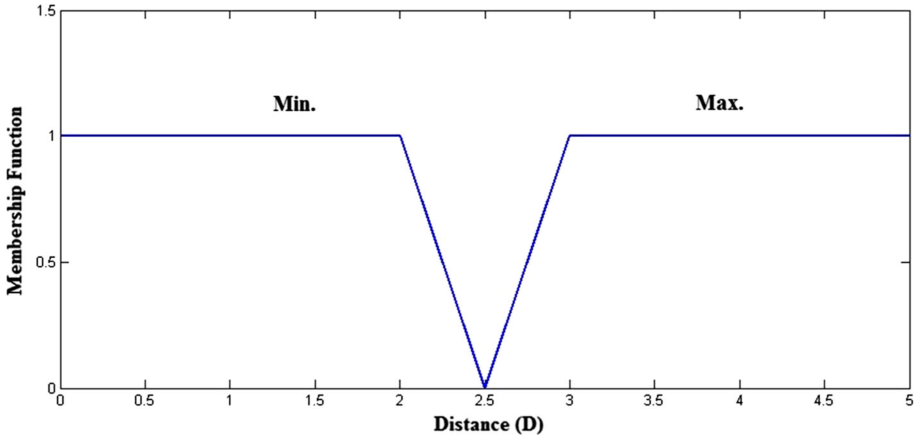


Fig. 5 Membership function of distance (D)

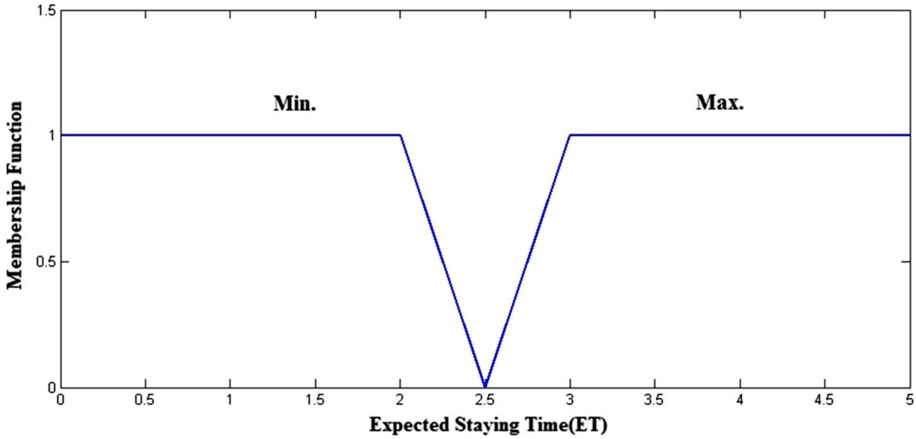


Fig. 6 Membership function of expected staying time (ETT)

agents that are responsible for a new route generation are forward ant (FANT) and backward ant (BANT).

Let S be the requesting node (Source), N_i be the intermediate node

The following are the steps that have been involved:

1. N_i is represented as each node that is made to inspect its routing table in order to regulate the fact that the information of the valid routing exists for RN.

   If valid data exists

   Then

   Node chooses the RN with the less number of hops. This is done for data transmission.

   Else

   Performs swarm based routing.

   End if

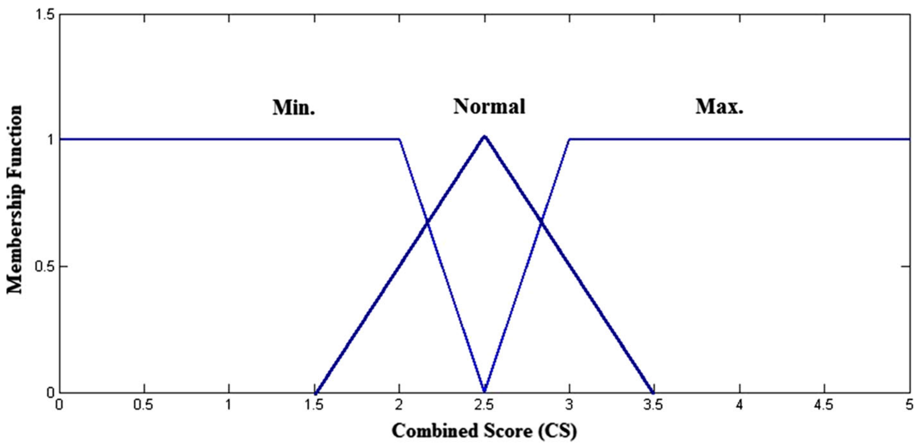


Fig. 7 Membership function of combined score (CS)

Table 1 The instance of knowledge base evaluation

S. no.	ET (Maximum)	BL (Maximum)	BW (Maximum)	D (Least)	LQ (Maximum)	Combined score
1	Least	Least	Least	Least	Least	Least
2	Least	Least	Least	Least	Maximum	Least
3	Least	Least	Least	Maximum	Minimum	Least
4	Least	Least	Maximum	Maximum	Minimum	Least
5	Least	Least	Maximum	Maximum	Maximum	Least
6	Least	Maximum	Least	Minimum	Least	Least
7	Least	Maximum	Least	Maximum	Maximum	Normal
8	Least	Maximum	Maximum	Minimum	Least	Least
9	Least	Maximum	Maximum	Maximum	Maximum	Normal
10	Maximum	Least	Least	Least	Least	Least
11	Maximum	Least	Least	Least	Maximum	Least
12	Maximum	Maximum	Maximum	Least	Maximum	Minimum
13	Maximum	Maximum	Maximum	Least	Least	Normal
14	Maximum	Maximum	Maximum	Maximum	Minimum	Maximum
15	Maximum	Maximum	Maximum	Maximum	Maximum	Normal

2. Initially S launches FANT. Depending on the probability probabilistic decision rule, the FANT visits each N_i (shown in Eq. 7).

$$\mathrm{P_r}(\mathrm{N_i}, \mathrm{S}) = \begin{cases} \dfrac{[a(N_i,S)]^{\zeta}\cdot[b(N_i,S)]^{\sigma}}{\sum_{N_i \in N_R}[a(N_i,S)]^{\zeta}\cdot[b(N_i,S)]^{\sigma}}, & \text{if r} \notin RT(N_i) \\ 0, & otherwise \end{cases} \quad (7)$$

where $a(N_i, S)$ characterize pheromone assessment, (N_i, S_o) signifies the value obtained experimentally which is related to the bandwidth, N_R signifies the receiver node, RT (N_i) signifies the routing table for N_i, ζ and σ are the two limits that regulates the qualified weight of the pheromone and heuristic value respectively.

3. A quantity of pheromone is deposited by each FANNT ($\Delta\tau^{u}(r)$) in the staying node N_i which is defined by the succeeding equation

$$\Delta\tau^{u}(r) = 1/X_{s}^{u}(r) \tag{8}$$

where the total number of nodes N_i that is stayed by the FANT with an iteration r and u = 1, 2…n is $X_{s}^{u}(r)$.

4. By means of rule that is defined in step 2, FANT traffics over node N_i and verifies the existence of RN ID in its routing table.

If RN ID exists,
Then
BANT is generated in respective N_i and the information collected by FANT is transferred to BANT.
End if

5. The path taken by ant is followed by the BANT. This takes place in an opposite direction. With the respective N_i, pheromone table is updated with the routing information
6. The S after receiving the BANT collects all the information regarding the routing about the N_i along every pathway since its efficient pheromone table.

The S chooses the route that has minimum hop after collection of all the information. The route has chosen with a primary path leading to a data transmission to RN

3.4 Cache Consistency

In this section to describe cache consistency using Push–Pull algorithm by associating cache-copy with a time-out value (u) with low cost.

This technique involves two actions:

- Push: S informs caching nodes about cache information.
- Pull: Hoarding node raises cache evidence since S.

The combined push–pull action on the caching and source node is described as.

1. When a query is received, the following condition is verified

   - If u > 0
   - Then
   - The received query is offered with the cached copy.
   - Else
   - u is decreased to zero.
   - A renewal message is transmitted to perform renewal of u from S and cache copy is Updated.
   - The received query is offered with the cached copy.
   - End if

2. When S is prepared for an updating, a message which is invalid is made to reach the entire caching node a value that is positive. The value is denoted as u.

$$S \longrightarrow \{u\}\{invalid\_mes\}CN$$

3. If S receives an acknowledgment message (ACK_ message) for each invalid message, the source data is updated.

$$\mathrm{S}\overset{ACK\_mes}{\longleftarrow}\mathrm{CN}$$

4. Following the reception of renewal message from CN

   - If source data has been updated
   - Then
   - An update message has been transmitted to CN
   - End if

5.

   - If there is no pending update
   - Then
   - Timeout u is allowed and data is updated to CN
   - End if

3.5 Proposed Cooperating Caching Model

We have proposed Mobility based Energy Efficient Cooperative Caching (MCE2C2) method. Mobility in MWSN can be made to use by having a base station that is mobile. In this mobility based clustering communication energy model, the equal grids are formed. These grids are called as the clusters. All the nodes in the cluster are taken care by the cluster head. The cluster head present in the group is responsible for all the communication that takes place. Hence the other nodes present in the network are only used for sensing process.

In this model first cache decision is done for each of the nodes. Once the cache decision is done, the Mobile nodes are arranged in a cluster. To maintain the energy efficiency clusters, the Cluster Head is responsible to collect all the information and communicate with mobile entity. To enhance the energy efficiency and to reduce the delay EECRT-Opt is estimated which gives optimal value for cache size and measures the time taken for cache replacement [32, 33]. Figure 8 represents the proposed cooperative caching model.

3.5.1 Caching Decision

In our proposed method, first caching decision is done by considering the following three cases:

Case 1 By considering Observed Information

Once the node N_i receives the data, the caching decision is made using two observations such as overhear queries as well as information such as node should be one hop distance on the wireless channel. Based on the observed information, the node estimates the information presence index η_i which can be given as below:

$$\eta_i(N_i, L) = \min\{1, C_{i1}(N_i, L) + C_{i2}(N_i, L)\} \tag{9}$$

where L represents time step

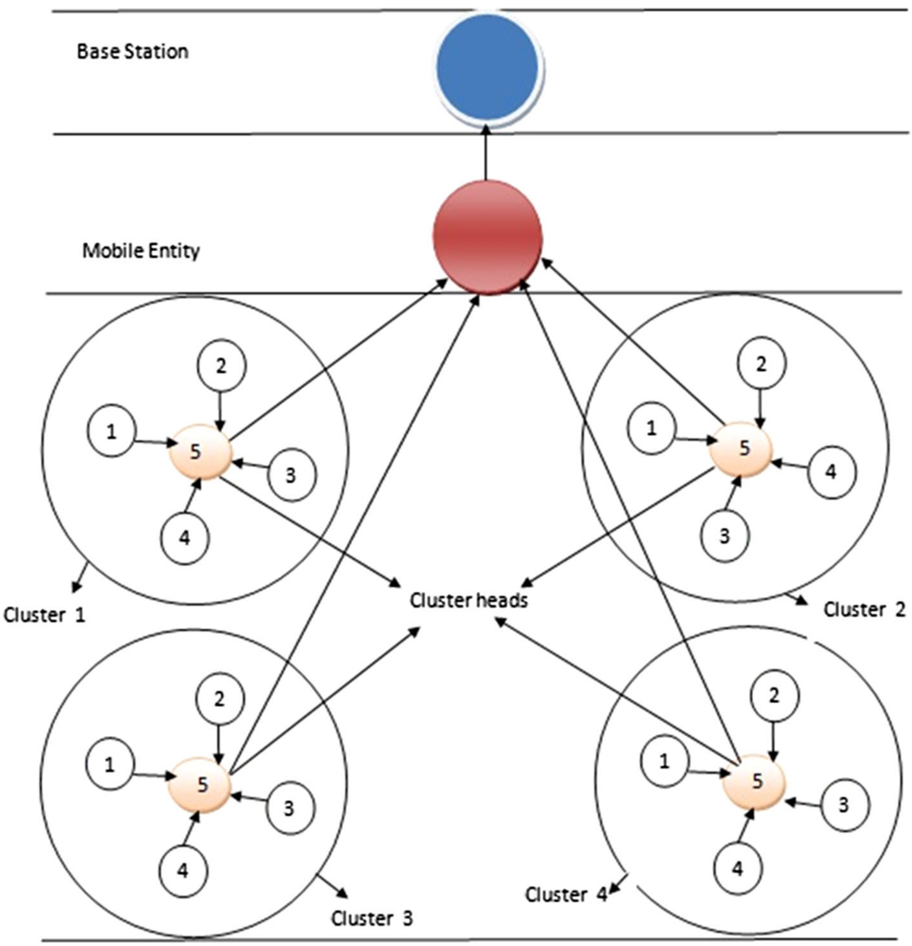


Fig. 8 Mobility with clustering mechanism

$C_{i1}(N_i, L)$ represents source counter. It reveals the existence of new copies of information γ deposited by node N_i to the Cluster Head. This counter value is updated each time node acts as S.

$$C_{i1}(N_i, L) = C_{i1}(N_i, L) + \frac{1}{H} \tag{10}$$

where H = number of hops travelled by new copies of data.

$C_{i2}(N_i, L)$ represents movement counter.

C_{i2} reveals the existence of γ between two nodes within transmission range and overheard by N_i at time step L.

$$C_{i2}(N_i, L) = C_{i1}(N_i, L) + \frac{1}{H_1} + \frac{1}{H_2} \tag{11}$$

H_2 represents number of hops covered by existing copies of data.

$\eta_i(N_i, L)$ lies in the range (0,1).

$$0 \rightarrow \textit{occurrence of } \gamma \textit{ was not sensed by } N_i \textit{ during } L$$

$$1 \rightarrow \textit{If } \gamma \textit{ is cached one hop away from } N_i$$

Case 2 Large-Sized Cache

In case N_i contains large-sized cache, η_i computes the cache drop time $T_D(N_i, L)$ at time step L for information i.

$$T_D(N_i, L) = (1 - \eta_i(N_i, L))T_{D\max} \tag{12}$$

where $T_{D\max}$ represents maximum cache drop time.

Case 3 Small-Sized Cache

When N_i contains a small sized it performs, cache content replacement technique. This unique technique allows removing chunk of information in regards with the content that arrives from the memory.

Once data is received at time step L, and if the memory space exceeds, then N_i discards the chunks of γ associated with the highest information presence index till the remaining data fit the storage limitation.

$$\hat{T}_D(N_i, L) = \left(1 - \frac{\hat{\eta}_i(N_i, L)}{\max\{\hat{\eta}_i(N_i, L)\}}\right)T_{C\max} \tag{13}$$

where $T_{C\max}$ represents maximum cache stability time.

After $T_{C\max}$, the residue is rejected in order to safeguard the store information from being outdated that is stored. Also the node movement is protected to discrepancy with esteem to earlier data η_i ratings.

3.5.2 Selection of Cluster Head

Once the cache decision is made, then all the sensor nodes are arranged in a cluster then such a way that they are at one hop distance with each other. It is well known that there are numerous heterogeneous sensor nodes in the MWSNs. All are connected randomly irrespective of associated in any of the topology present. Moreover, it is very complicated for a sensor node in order to get information that is received from the source each and every time, as it increases the latency as well as consumption of resources. In our proposed architecture, first we selected a Cluster Head that serves all its members.

The follow are the four parameters that has been considered, in order to select a Cluster Head are as follows:

- Mobility (M)
- Energy Level (EL)
- Memory Size (MS)
- Processing Power (P)

All the sensor nodes that are present in the network consist of specific energy level, mobility, processing power and memory size. The main aim behind calculating all the parameters is to find the value of the robust known as the Stability Factor (SF). One more important consideration in our architecture is that each node in the network floods the nodes that are nearby that is that are at one hop distance.

For the Cluster Head election, Stability Factor can be calculated from Eq. (14):

$$SF_H = \frac{\langle EL(x) \times MS(x) \times P(x) \rangle}{M(x)} \tag{14}$$

The step considered for Cluster Head Selection is considered as below:

Step 1: Flood the network with Sensor Node (SN) with its (ID, MS, EL, P, and M)
Step 2: For each node in the network, calculate SF_H and update in the Table 2
Step 3: Arrange them in decreasing order
Step 4: Sensor node with the highest Stability Factor will be selected as Cluster Head
Step 5: the nodes which are present in the one arm distance readily joins and become the cluster head and makes sure that it does not join the election
Step 6: The re-election is done in case the current cluster head leaves the network. This takes place among t the current members in the cluster

3.5.3 Dynamic Cluster Management

Cluster Management over MWSN needs managing mobility and produced changes in a cluster membership, this in such a way that the application is not seen outside. In case of a new node is suspected around the network, and then it is officially invited to join the network that has a cluster. This is provided on the base of the in-house. It is known that battery power of the Cluster Head may decrease but not of the other member. Hence re-election can take place from the other group member which is explained as below:

Step 1: Check Energy_Level of Cluster Head
If Energy_Level> Threshold Energy
Then re-election not needed
Else
If Energy_Level <Threshold Energy
Then broadcasts an Energy_Low message to all its neighbors
Step 2: Perform re-election
Step 3: Calculate SF_H
Step 4: Mobile node with highest Stability Factor value is selected as new Cluster Head respectively

3.6 Energy Efficient Cache Replacement Algorithm (EECRA)

Finally we integrate the cache consistency with cache replacement using energy-efficient cache Replacement Algorithm (EECRA) [34]. This algorithm provides optimal solution that meets our aim of higher energy efficiency without any much delay of MWSNs.

Table 2 Node Status

Node Status					Stability Factor
ID	Memory Size	Energy Level	Processing Power	Mobility	SF_H

3.6.1 Assumption

Assume that size of N_0 is S and $C = \{C_1, C_2, \ldots C_m\}$ represents set of cached objects and their $size_{C_1}, size_{C_2}, \ldots size_{C_m}$ respectively. In order to maximize the benefit, let us consider $T_j(j = 1, 2, \ldots m)$ represents time taken to fit the size of the cache C_j.

Our main aim is to maximize

$$\sum_{j=1}^{m} benefit(C_j)T_j \tag{15}$$

Subject to

$$\sum_{j=1}^{m} size_{C_j}T_j \leq S - size_{\gamma_K}T_j = \in \{0, 1), \quad j = 1, 2\ldots m \tag{16}$$

3.6.2 EECRA-OPT Algorithm

The time taken to solve the EECRT problem is known as the pseudo-polynomial time that is done using dynamic programming. Considering a pair of the integer $\delta(1 \leq \delta \leq m)$ *and* $u\left(0 \leq u \leq S - size_{\gamma_k}\right)$, contemplate the sub case of EECRA that includes new information $\gamma_1, \gamma_2, \ldots\gamma_\delta$ *and capacity as u.*

Let $g(\delta, u)$ denote its optimal solution value i.e.

$$g(\delta, u) = \max\left\{\sum_{j=1}^{\delta} benefit(C_j)T_j : \sum_{j=1}^{\delta} size_{C_j}T_j \leq u, \quad T_j \in \{0, 1\}\right\} \tag{17}$$
$$for\, j = 1, \ldots \delta$$

We have,

$$g(1, u) = \begin{cases} 0.\, for\ u = 0, \ldots, size_{C_1} - 1; \\ benefit(C_1), \quad for\ u = size_{C_1}\ldots S - Size_{\gamma_K} \end{cases} \tag{18}$$

$$g(\delta, u) = \begin{cases} g(\delta - 1, u), \\ for\ u = 0, \ldots size_{C_m} - 1 \\ \max(g(\delta - 1, u), g(\delta - 1, u - size_{C_m})) + benefit(C_m) \\ for\ u = size_{C_m}, \ldots S - size_{\gamma_K} \end{cases} \tag{19}$$

The optimal solution for the problem is $g\left(m, S - size_{\gamma_K}\right)$.

Advantages of the proposed approach

- The use of Fuzzy logic decision rules, increase the accuracy of QD node selection.
- Mobility based clustering model was proposed to improve sensor node energy in MWSNs

4 Results and Discussions

The Experimental results are evaluated based on the proposed approach (MCE2C2) comparing to conventional caching methods NICaCo [11], C3S [32] and E3C2 [2] using MATLAB and Network Simulator NS2. Table 2 summarizes the parameter of NS-2 simulator, by default setting a movement of 500 sensor nodes in a 3450 × 3450 m^2 region that is about 100 s of the total simulation time. The transmission range of 300 m has been set as common for all the nodes. The Constant Bit Rate (CBR) is simulated.

The Table 3 shows the parameter that consists of the simulation settings.

The Simulation topology is shown in the following Fig. 9

4.1 The Performance Metrics

The performance of proposed structure (MCE2C2) for MWSNs is compared with conventional caching methods like NICoCa, C3S and E3C2 rendering to the subsequent metrics.

- *Packet Delivery Ratio* The ratio that deals with total number of data packets that has been sent and the total number of data packets has been received.
- *Packet Drop* It denotes the regular amount of packets that are dropped throughout the communication.
- *Delay* delay is said to be the required time taken for a node to transmit the data in the network.
- *Energy Utilization* It is an energy utilization to processing query by the sink node.
- *Throughput* It is the total number of packets that are received successfully by the receiver.

4.2 Results

4.2.1 Evaluation Effect of the speed

The mobile speed is varied in our experiment as 5, 10, 15, 20 and 25 m/s. The Performance evaluation of speed based on metrics is illustrated in Fig. 10.

Figure 10a illustrates the evaluation effect of speed on delay. The result of MCE2C2 is compared with that of NICoCa, E3C2, and C3S. It is observed from the Fig. 10a when the speed is increased automatically there is an in the delay too, which result in route

Table 3 Simulation parameter

Parameter	Symbol	Value
Number of sensor nodes	N	500
Network coverage area	A	3450 × 3450 m^2
Speed	S	5, 10, 15, 20, 25 m/s
Transmission rate	T	300 kb
Mutimedia data	M_d	32 kb
Cache size	CS	250, 500, 750, 1000
Location of sink	LS	(0, 0)
Energy of initial node	EN	3 J

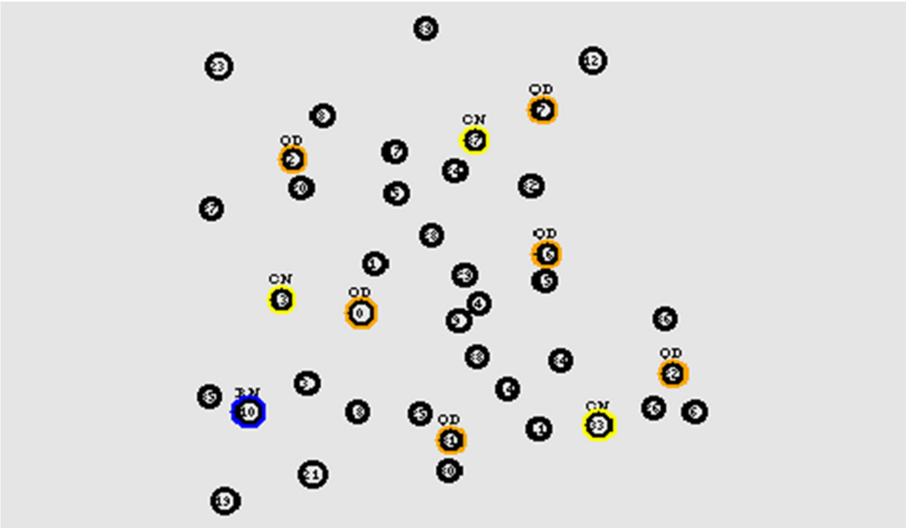


Fig. 9 Simulation topology

breakages. By use of proposed cooperative caching scheme, the conclusion can be done by saying that the delay that has been obtained in the method that has proposed MCE2C2 has 10 % reduced than that present in the approaches that are already present.

Figure 10b illustrates the evaluation effect of speed on the delivery ratio. It is observed from the Fig. 10b, that there is lot of chance of route to fail when the speed of the data transmission increases. Using comprehensive method like making the nodes into a cluster form and by using the policy of replacement, the MCE2C2 technique outperforms other methods under different speed settings. By use of proposed cooperative caching scheme, it can be finally said that the proposed approach MCE2C2 has 5 % advanced than the existing approaches.

Figure 10c illustrates the evaluation effect of speed on the drop. It is observed from the Fig. 10b that the delivery ratio decreases whenever the drop ratio increases. Using our approach the delivery ratio is increased when compared to the existing approaches. So the fall of packets in the network when used the approach MCE2C2 has become 10 % lesser than existing approaches.

Figure 10d illustrates the evaluation effect of speed on Energy Utilization. The Fig. 10b shows that is a result of increase in the delivery ratio more data can be given or rather shared by the sensors that are present nearby this can reduce the number of data that are sent. Though, the performance of utilizing the best of the energy reduces or become less in the network as the size of the network increases. By use of proposed caching, it has been concluded that the energy utilization present in the system that was proposed that is the MCE2C2 has 10 % of lesser than existing approaches.

Figure 10e illustrates the evaluation effect of speed on Throughput. The throughput is calculated between a node and its neighbors. It has also been found out that the throughput of the system that was proposed that is MCE2C2 is far better than the existing approaches.

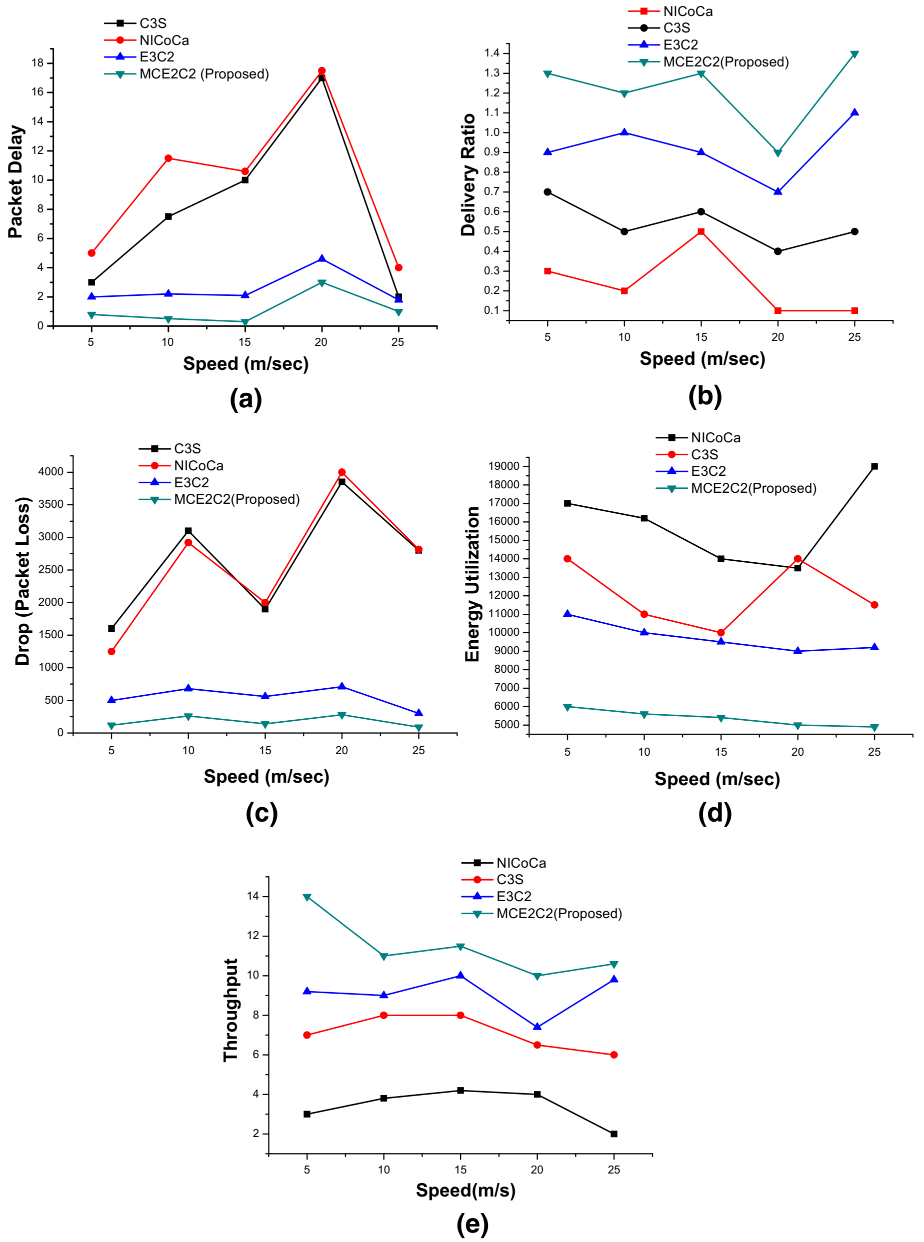


Fig. 10 Speed of the node evaluation **a** packet delay, **b** delivery ratio, **c** drop, **d** energy utilization, **e** throughput

4.2.2 Evaluation Effect of Cache Size

In our second experiment, the cache size is varied to 200, 400, 600, 800, 1000, 1200 and 1400. The Performance evaluation of cache size is based on metrics as illustrated in Fig. 11.

Figure 11a illustrates the evaluation effect of cache size on packet delay. It is observed from the Fig. 11a that the delay that is obtained by evaluating the effect of Cache Size in our proposed method has 10 % lesser than the existing approaches.

The delivery ratio and drop for the proposed and the existing are shown in Fig. 11b, c correspondingly. The data-transfer packets reduce with the increase in the size of the packet. This can sometimes lead loss in the packet. Hence by applying the proposed method, there is an assurance that along with the increase size of packet, there is less decrease in the size of the packet and also in the delivery ratio. The result findings from the

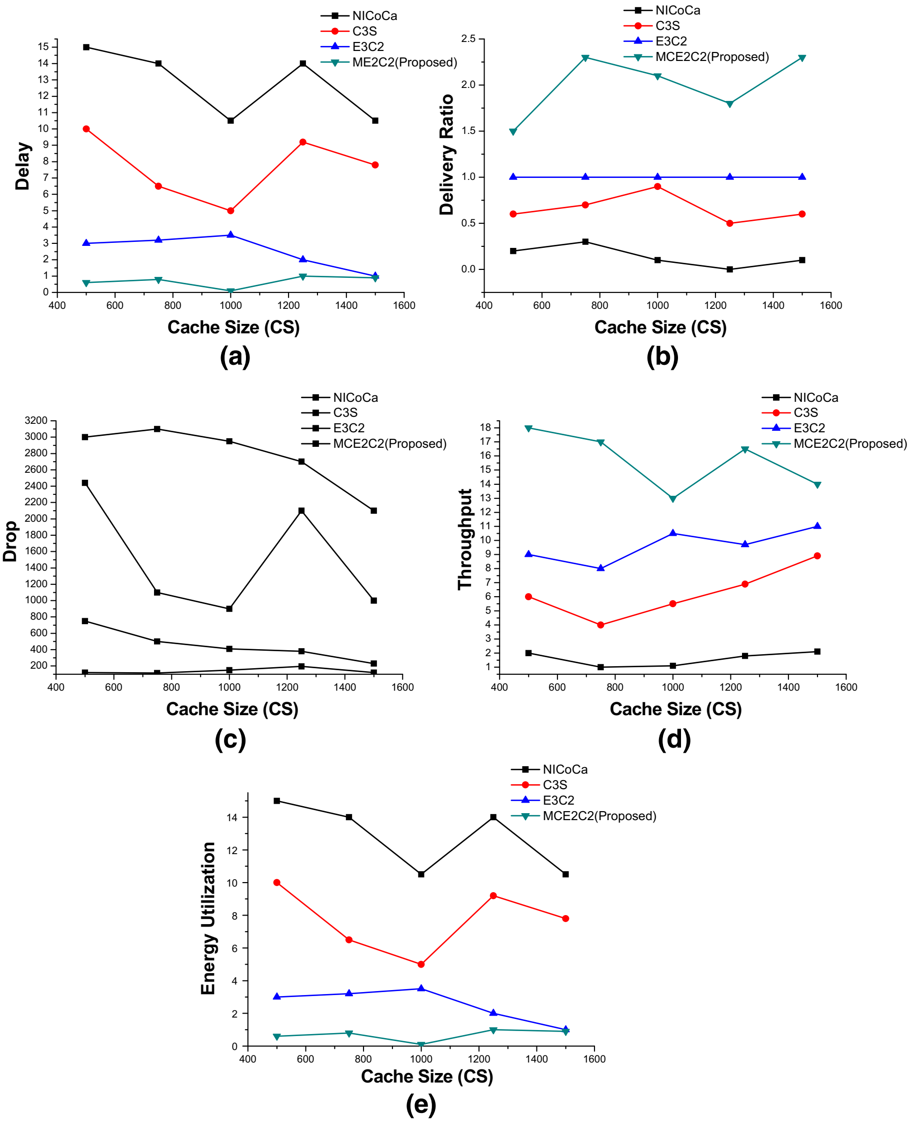


Fig. 11 Evaluation effect of cache size on **a** delay, **b** delivery ratio, **c** drop, **d** throughput, **e** energy utilization

above figures show that the delivery ratio increases, automatically the packet drop is reduced up to 5 % when compared to existing methods. Therefore the delivery ratio of MCE2C2 has increased by 10 % advanced than the existing approaches.

Figure 11d illustrates the evaluation effect of cache size on throughput. It can be observed from the Fig. 11d that the throughput of the method that has been proposed MCE2 C2 approach is better than that of the present methods.

Figure 11e illustrates the evaluation effect of cache size on Energy Utilization. At little cache size, less number of requirements is fulfilled from the nearby cache, accordingly expanding the energy utilization. As delivery ratio increases, more information might be shared from the close-by sensor nodes, in this way reducing the quantity of transmissions and consequently energy utilization.

MCE2C2 have always lower energy utilization than the existing approaches. So, we can conclude that the energy utilization of MCE2C2 is 10 % lesser than the current methods.

5 Conclusion

The current research article, the Mobility with Clustering based Energy Efficient Cooperative Caching (MCE2C2) framework has been proposed. In this framework for supporting large number of multimedia image and video transmission with efficient sensor node energy and quality services in MWSNs. In this the mobile entity are dealt by the cluster head. The all other nodes that are present in the cluster are used only for the sensing purpose. Because of this, large amount of energy get saved when only one head node communicated rather than all the nodes communicating. In addition, we have integrated the cache consistency and cache replacement algorithms so as to find the optimal explanation leading to advanced cache hit ratio, hence the admittance delay is reduced with low energy costs of MWSN sensor nodes. The result is finding from Figs. 10 and 11 shows that, at little cache size less number of requirements is fulfilled from the nearby cache, accordingly expanding the energy utilization. As delivery ratio increases, more information might be shared from the close-by sensor nodes, in this way reducing the quantity of transmissions and consequently energy utilization. By comprehensive simulation result of the MCE2C2 demonstrates that sensor node energy has been improved by 10 % in terms of speed and cache size in comparison with NICoCa, E3C2, C3S methods.

References

1. Li, N., Martinez, J.-F., & Diaz, V. H. (2015). The balanced cross-layer design routing algorithm in wireless sensor networks using fuzzy logic. *Sensor, 15*, 19541–19559.
2. Chand, N. (2014). Energy efficient cooperative caching in wireless multimedia sensor networks. *Advances in information Science and Applications, II*, 634–639.
3. Ghaeini, H. R., Akbari, B., Barekatain, B., & Cabrera, A. T. (2015). Adaptive video protection in large scale peer–peer video streaming over mobile wireless mesh networks. *International Journal of Communication Systems.* doi:10.1002/dac.3088.
4. Behrang, B., Khezi Motlagh, D., Aizaini Maarof, M., Ghaeini, H., Ariza Quintana, A., & Trivino Cabrera, A. (2014). Efficient P2P live video streaming over hybrid WMNs using random network coding. *Wireless Personal Communications, 80*(4), 1761–1789.
5. Chen, J., & Zhou, H. (2014). Cooperative energy efficient management scheme for multimedia information dissemination. *International Journal of Distributed Sensor Networks.* doi:10.1155/2014/718403.

6. Xu, J., Li, K., Shen, Y., & Liu, J. (2008). An energy-efficient waiting caching algorithm in wireless sensor network. *International Conference on Embedded and Ubiquitous Computing., 1*, 323–329.
7. Leung, L. W., King, B., & Vohra, B. (2011). Comparison of image data fusion techniques using entropy and INI. In *Asian Conference on Remote Sensing*.
8. Tseng, V. S., Hsieh, M.-H., & Lin, K. W. (2011). A novel cache replacement algorithm for cooperative caching in wireless multimedia sensor networks. *International Journal of Innovative Computing, Information and Control, 7*(2), 763–776.
9. Zhang, W., Yin, L., & Cao, G. (2004). Secure cooperative cache based data access in ad hoc networks. In *NSF International Workshop on Theoretical and Algorithmic Aspects of Wireless Ad Hoc, Sensor, and Peer-to-Peer Networks*.
10. Yin, L., & Cao, G. (2006). Supporting cooperative caching in ad hoc networks. *IEEE Transactions on Mobile Computing, 5*(1), 77–89.
11. Dimokas, N., Katsaros, D., Tassiulas, L., & Manolopoulos, Y. (2011). High performance, low complexity cooperative caching for wireless sensor networks. *Wireless Networks, 17*(3), 717–737.
12. Artail, H., & Saab, S. (2009). A distributed system for consuming web services and caching their responses in MANETs. *IEEE Transactions on Services Computing, 2*(1), 17–33.
13. Dimokas, N., Katsaros, D., Tassiulas, L., & Manolopoulos, Y. (2008). Cooperative caching in wireless multimedia sensor networks. *Mobile Network Applications, 13*(3/4), 337–356.
14. Huang, Y., Cao, J., Jin, B., Tao, X., Lu, J., & Feng, Y. (2010). Flexible cache consistency maintenance over wireless ad hoc networks. *IEEE Transactions on Parallel and Distributed Systems, 21*(8), 1150–1161.
15. Artail, H., Safa, H., Mershad, K., Abou-Atme, Z., & Sulieman, N. (2008). COACS: A cooperative and adaptive caching system for MANETs. *IEEE Transactions on Mobile Computing, 7*(8), 961–977.
16. Chakravorty, C., & Usha, J. (2012). Cache management issues in mobile computing environment. *International Journal of Mobile Network Communications and Telematics (IJMNCT), 2*(1), 21–27.
17. Dan, G. (2011). Cache-to-cache: Could ISPs cooperate to decrease peer-to-peer content distribution costs. *IEEE Transactions on Parallel and Distributed Systems, 22*(9), 1469–1482.
18. Fiore, M., Casetti, C., & Chiasserini, C.-F. (2011). Caching strategies based on information density estimation in wireless ad hoc networks. *IEEE Transactions on Vehicular Technology, 60*(5), 2194–2208.
19. Phaneendra, Ch., Srimathi, K., Shekhar, T.P., Ravi Kumar, V. (2012). Caching approach foundation on information density evaluation in wireless ad hoc networks. *International Journal of Advanced Research in Computer Science and Software Engineering, 2*(5).
20. Srinivas, C., & Khan, S. (2012). Data caching placement based on information density in wireless ad hoc network. *International Journal of Engineering Research and Applications, 2*(4), 120–125.
21. Paul, P. V., Rajaguru, D., Saravanan, N., Baskaran, R., & Dhavachelvan, P. (2013). Efficient service cache management in mobile P2P networks. *Future Generation Computer Systems, 29*, 1505–1521.
22. Xu, X., & Liang, W. (2011). Placing optimal number of sinks in sensor networks for network lifetime maximization. In *IEEE International Conference Communications (ICC)*, pp. 1–6.
23. Sabiyath Fatima, N., & Sheik Abdul Khader, P. (2011). A hybrid cache invalidation technique for data consistency in MANET. *International Journal of Computer Applications, 16*(5), 0975–8887.
24. Kuppusamy, P., & Kalaavathi, B. (2012). Cluster based data consistency for cooperative caching over partitionable mobile adhoc network. *American Journal of Applied Sciences, 9*(8), 1307–1315.
25. Fan, X., Cao, J., & Wu, W. (2011). Contention-aware data caching in wireless multi-hop ad hoc networks. *Journal of Parallel and Distributed Computing, 71*(4), 603–614.
26. Artail, H., Al-Asadi, H. (2006). A cooperative and adaptive system for caching web service responses in MANETs. In *IEEE International Conference on Web Services* (pp. 339–346). IEEE.
27. Mershad, K., & Artail, H. (2011). CODISC: Collaborative and distributed semantic caching for maximizing cache effectiveness in wireless networks. *Journal of Parallel and Distributed Computing, 71*, 495–511.
28. Fatima, M., Gupta, R., & Bandhopadhyay, T. K. (2012). Route discovery by cross layer approach for MANET. *International Journal of Computer Applications, 37*(7), 14–24.
29. Chand, N. (2013). Energy efficient cooperative caching in WSN. In *International Conference on Computer and Communication Networks Engineering (ICCCNE)*, pp. 674–679.
30. Seraphin, G. B., & Ramesh, S. (2013). QoS provisioning in seamless vertical handover of WIMAX/WLAN overlay network. *International Journal of Emerging Technology and Advanced Engineering, 3*(3), 158–162.
31. Ganesan, I., & Karuppasamy, M. (2011). An efficient cross-layer scheduling with partial channel state information. *Informatica, 35*(2), 245–250.

32. Chand, N. (2013). Energy efficient cooperative caching in WSN. In *International Conference on Computer and Communication Networks Engineering (ICCCNE)*, pp. 674–679.
33. Chauhan, N., Awasthi, L. K., Chand, N., Joshi, R. C., & Misra, M. (2010). Energy efficient cooperative caching in mobile ad hoc networks. *International Journal of Applied Engineering Research, 1*(3), 360.
34. Li, W., Chan, E., Chen, D. (2007). Energy-efficient cache replacement policies for cooperative caching in mobile ad hoc network. In *Wireless Communications and Networking Conference, WCNC 2007, IEEE 2007.*

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