MiW: An MCC-WMSNs Integration Approach for Performing Multimedia Applications

Joy Lal Sarkar[1](✉), Chhabi Rani Panigrahi[1], Bibudhendu Pati[2], and Rajendra Prasath[3]

[1] Department of Computer Science, Central University of Rajasthan, Ajmer, India
joylalsarkar@gmail.com, panigrahichhabi@gmail.com

[2] Department of Computer Science and Engineering, C.V. Raman College of Engineering, Bhubaneswar, India
patibibudhendu@gmail.com

[3] Department of Computer and Information Science, Norwegian University of Science and Technology, Trondheim, Norway
drrprasath@gmail.com

Abstract. The popularity of multimedia applications are growing day-by-day. Emerging Mobile Cloud Computing (MCC) and Wireless Multimedia Sensor Networks (MCC-WMSNs) help to work efficiently with these multimedia applications. The advantage of integrating MCC with WMSNs is that the data gathered by sensor nodes can be accessible from anywhere and at anytime by the users. In this context, there exists several issues such as battery life of the multimedia sensors, processing power, and storage etc. To solve these problems, in this work a MCC-WMSNs integration technique is proposed by using a cloudlets based integration algorithm named as CLIW which mainly works with CLIW-1 and CLIW-2 schemes where both the schemes focus on minimizing energy consumption. The simulation results indicate that CLIW-1 and CLIW-2 schemes are able to prolong the network lifetime of integrated WMSNs.

Keywords: Network lifetime · Multimedia applications · MCC · WMSNs

1 Introduction

The number of smart phone users in India is around 204.1 million and more than 2 billion users in the world and the number is expected to touch 2.7 billion by 2019 [1]. The popularity of using smart phones across the globe is growing due to development of many complex and feature rich applications. In MCC, there are mainly three players: cloud computing, mobile computing, and wireless networks [2]. Cloud computing helps when complex computations are required to perform, where the computation and storage is offloaded by MCC to the cloud.

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Mobile computing helps to perform the computations in the mobile device itself and hence there is no energy required for offloading purposes [3]. The network is required by the sensor nodes to transfer the data to the mobile for computation purposes. Often the offloading approach is used in MCC, as it may be required when computation is complex and cloud is required to undertake computation and storage activity [4,16]. The results from the cloud are then passed back to the users of mobile devices.

Multimedia aggregates numerous types of contents that are present in varied format and hence dealing with them is quite complex at times. The usage of multimedia started with movies and now spread to other fields such as gaming, medical, education, various computer simulations, home shopping, and training etc. [14,15].

It is of utmost importance that the integration architecture designed should be technically sound and also cater to the applications in various domains (such as banking, telecom, etc.) so that the MCC and WMSNs integration is fully justified. Also, the integration sometimes is a challenge task as both MCC and WMSNs have limited power and therefore it becomes necessary to ensure that energy saving techniques are kept in mind while doing the integration such that the WMSNs devices can function for a longer life and consume energy only when required to reduce the wastage such as in case of Always On (AO) state [5].

In this work, an energy efficient transmission between WMSNs and mobile devices has been proposed named as MiW. The MiW technique provides an efficient connection between sensor nodes and mobile devices. The proposed technique works based on CLIW scheme where CLIW scheme is further divided into CLIW-1 and CLIW-2 schemes. The proposed MiW technique is mainly designed to improve the energy efficiency of multimedia sensor nodes when integrated with MCC. The proposed technique also helps to improve the degree of computation and resources by considering Cloudlets (CLs).

The rest of the paper is organized as follows: Sect. 2 describes the related work. Section 3 describes the proposed MCC-WMSNs integration model along with CLIW scheme. Section 4 presents the simulation obtained along with the analysis of results. Finally, the paper is concluded in Sect. 5.

2 Related Work

In [14], Wang et al. discussed about Cloud Mobile Media (CMM) applications and how offloading done through MCC helps multimedia applications which need computationally intensive and huge network bandwidth for processing. Zhu et al. [6] discussed about the integration of MCC and WSNs in a manner that is energy efficient and at the same time the transmitted data is also valuable. Das et al. [7] considered the case of health monitoring of the patients using sensors that are attached to their body. The resources in the cloud are assigned to processes depending on their expected utilization and priority is given to the process who uses the highest number of resources.

In [8], an integration mechanism has been proposed between different types of sensors which transmit data which is then processed and culminated using advanced machine learning algorithms and subsequently help out in the irrigation process. Shah et al. [9] discussed about the integration among WSNs, Internet, and cloud in an effective manner that reduces cost and also saves energy. The authors also suggested an architecture which uses efficient algorithms to send the message about the patients deteriorating medical condition to the right doctor.

Chen et al. [10] proposed an architecture where the cloud is leveraged for its vast computational power and storage for coming up with a service which rescues persons who are in danger and need immediate help. Zhu et al. [11] devised a MCC and WSNs integration framework which not only increases the life span of WSNs but also it is intelligent enough to forecast the data flow in a secure manner.

Zhu et al. [5] proposed a mechanism of MCC and WSNs integration which assumes that the smart mobile device users would mainly ask for data of vicinity areas. The authors have put forth two approaches: CLSS-1 where the sensor gets into active state at a particular location only and in CLSS-2 mainly the performance factor of the WSNs which is integrated with MCC is taken into account.

3 Integration Model of MCC-WMSNs

The architecture of MCC-WMSNs integration is shown as in Fig. 1(a) where for collecting data from WMSNs, the mobile user M_i sends data request to CL. CL then sends request to the sink node and the sink node then collects data from the sensor node and sends reply to CL. CL then sends reply to M_i. Figure 1(b) shows the mobility of the mobile devices where a mobile device moves from one place to another. When M_i is shifted to another place and it is in the range of another CL then M_i sends request to the current cloudlet denoted as $CL_{current}$ for collecting the data from previous cloudlet denoted as $CL_{previous}$. If M_i does not receive the data from the CL when it is in the range of $CL_{previous}$ then M_i accesses those data from the $CL_{current}$.

3.1 CLIW Scheme

In this section, a cloudlet based integration algorithm CLIW is presented for MCC and WMSNs. CLIW scheme follows two schemes: CLIW-1 and CLIW-2. The pseudocodes of CLIW-1 as well as CLIW-2 scheme are described as follows.

CLIW-1 scheme: In CLIW-1 scheme, M_i sends data requests to the CL. The CL then determines whether the requested data is available in the CL or not. If the data is not available in the CL then CL sends a flag D to the sink node. The sink node then broadcasts the flag D to sensor nodes. The sensor nodes which receive the flag D then they maintain awake state otherwise they go to sleep state. During awake state, sensor nodes send data to the sink nodes. The sink node then aggregates the data and sends these to the CL and CL sends the reply to M_i (steps 1–6 of CLIW-1). Each M_i can move from one place to another. In such situation, if M_i could not able to collect the requested data from earlier

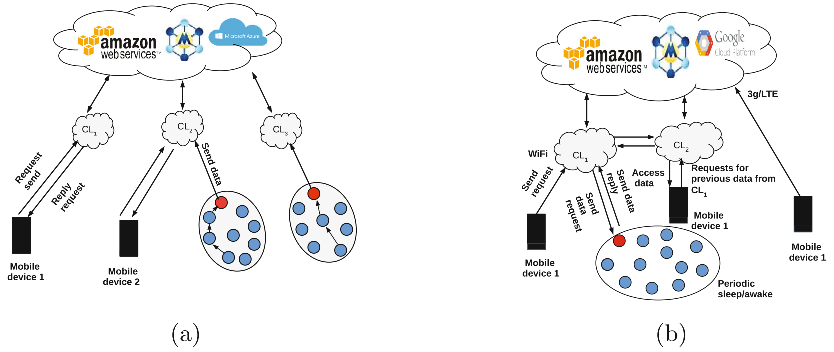


Fig. 1. (a) Architecture of MCC-WMSNs integration, (b) Mobility scenarios of mobile users

CL, then M_i sends request to the $CL_{current}$. The $CL_{current}$ then sends request to the earlier CL for collecting data. The $CL_{current}$ then collects data from the $CL_{previous}$ and sends to M_i. If M_i does not found any CL within its range then it is connected with Central Cloud(CC) (steps 7–9 of CLIW-1).

Algorithm 1. *CLIW*-1 Scheme

1: Mobile device M_i sends data request DR to CL
2: If DR is not available in CL then CL sends a flag D to sink node S_i
3: S_i broadcasts a flag D to sensor nodes
4: If a node n_i receives the flag D, it remains awake and sends reply to S_i otherwise it goes to sleep state
5: S_i aggregates the data and sends reply to the CL
6: CL sends data to M_i
7: If M_i moves to next CL without receiving data then M_i sends request to $CL_{current}$ for accessing data from $CL_{previous}$
8: $CL_{current}$ collects data from $CL_{previous}$ and sends to M_i
9: If there is no CL then M_i connects with CC

CLIW-2 scheme: According to CLIW-2 scheme, M_i sends data request to the CL. The CL then determines whether the requested data is available to the CL or not. If the data is not available to the CL then CL sends a flag D to the sink node.

The sink node replies based on the Residual based Sleep/Awake Scheme (RSAS). According to RSAS, it collects residual energy of 1 to (K-i) nodes ($R^e_{1to(K-i)}$). The nodes can connect to each other either by single hop or multi-hop. A node maintains a flag N if it satisfies two conditions: (a) if $R^e_i > R^e_{1to(K-i)}$ and (b) each node ensures that there are at least K neighbors of it (steps 1–3 of RSAS). CL sends reply to M_i. Each M_i can move from one place to another place. In such situation, if M_i could not be able to collect the requested data

Algorithm 2. CLIW-2 Scheme

1: Mobile device M sends data request DR to CL
2: If DR is not available to CL then CL sends a flag D to sink node S_i
3: S_i sends reply to CL based on RSAS
4: CL sends data to M_i
5: If M_i moves to next CL without receiving data then M_i sends request to $CL_{current}$ for accessing data from $CL_{previous}$
6: $CL_{current}$ collects data from $CL_{previous}$ and sends to M_i
7: If there is no CL then M_i connects with CC

Algorithm 3. RSAS

1: Collects current R_i^e
2: Node A connects with node B either by direct connection (single hop) or indirect connection (multi-hop)
3: Each node A awakes if it receives a flag N and then goes to sleep if
   (a) $R_i^e > R_{1to(K-i)}^e$
   (b) Each node ensures that there are atleast K neighbors of it

from $CL_{previous}$, then M_i sends request to the $CL_{current}$. The CL then sends request to the $CL_{previous}$ for collecting data. The $CL_{current}$ then collects data from the $CL_{previous}$ and sends to M_i. If M_i does not find any CL within the range of M_i then it connects with CC (steps 4-7 of CLIW-2).

3.2 Analysis of CLIW Scheme

We assume that in a 2-D area χ, N number of nodes are deployed in WMSNs. The node density denoted by ψ can be computed by using Eq. (1).

$$\psi = \frac{N}{\chi} \tag{1}$$

Now, from each n_i the distance of the nearest neighbor [12,13] denoted by $d(n_i, N_n)$ is computed by using Eq. (2).

$$d(n_i, N_n) = \frac{1}{2\sqrt{\psi}} \tag{2}$$

Let T be the time interval for node n_i when the expected number of events occur in WMSNs denoted by T^e and is computed by using Eq. (3).

$$T^e = \Psi.u \tag{3}$$

where, u denotes the probability that an event occurs.

Now, assuming that there are p_i number of packets that are transmitted from n_i after detection of an event. So, for each n_i, the total number of packets (P) that are transmitted can be computed by using Eq. (4).

$$P = \psi.\pi.T^2.p_i.\Psi.u \tag{4}$$

Now, for each sensor, the expected number of neighbors denoted by $exp(n)$ can be computed by using Eq.(5).

$$exp(n) = \psi.\pi.T^2 \quad (5)$$

Each sensor node maintains both sleep as well as awake state periodically under CLIW-1 scheme. If a sensor node does not receive any flag from CL then that sensor node gets back to the sleep state. So, the energy consumed by each n_i denoted by E_c^{CLIW1} and is computed by using Eq. (6) [5].

$$E_c^{CLIW1} = E^t.(\psi.\pi.T^2) + E^r + \frac{P(E^t + E^r)}{2} - \omega(CC) \quad (6)$$

In Eq. (6), $\omega(CC)$ denotes the extra communication cost which is considered as energy consumption due to high latency. The negative sign indicates that most of the time CLIW-1 ignore CC when CL is available. Here, E^t and E^r denote the consumption of energy for transmitting and receiving packets respectively. So, the network lifetime in CLIW-1 denoted as Ne(life1) and can be computed by using Eq. (7).

$$Ne(life1) = \frac{Io}{E^t.(\psi.\pi.T^2) + E^r + \frac{P(E^t+E^r)}{2} - \omega(CC))}.T \quad (7)$$

where, I_o denotes the initial energy of each sensor node.

Now, according to CLIW-2 scheme, the nodes are awake when they receive flag N from neighboring nodes. In such scenario, the nodes consume their energy. CLIW-2 scheme follows $RSAS$. Under $RSAS$, sensor nodes can be in awake state after satisfying both the conditions (a) and (b). So, each n_i consumes its energy under CLIW-2 scheme denoted by E_c^{CLIW2} and can be computed by using Eq. (8).

$$E_c^{CLIW2} = E^t.(\psi.\pi.T^2) + E^r + \frac{P(E^t + E^r)}{2} + \frac{(E^t + E^r)P^*}{2} - \omega(CC) \quad (8)$$

where, P^* denotes the total number of transmitted packets. The network lifetime in CLIW-2 denoted as Ne(life2) and can be computed by using Eq. (9).

$$Ne(life2) = \frac{\frac{I_o}{E^t.(\psi.\pi.T^2)+E^r+\frac{P(E^t+E^r)}{2}+\frac{(E^t+E^r)P^*}{2}} - \omega(CC)}{2}.T \quad (9)$$

The CL has limited resources and for that CL executes other jobs after execution of its own job and for that we use External Service Ratio (ESR) [14].

Theorem 3.1. *The network lifetime under CLIW-1 scheme is equal to the product of network lifetime of CLIW-2 and* $(2 + \frac{P^*}{p^*})$ if energy consumption during transmission is too high.

Proof. The ratio of the network lifetime between two schemes is given in the following:

$$\frac{Ne(life1)}{Ne(life2)} = \frac{Io}{E^t.(\psi.\pi.T^2) + E^r + \frac{P(E^t+E^r)}{2} - \omega(CC)}.T$$
$$\div \frac{\frac{I_o}{E^t.(\psi.\pi.T^2)+E^r+\frac{P(E^t+E^r)}{2}+\frac{(E^t+E^r)P^*}{2}-\omega(CC)}}{2}.T$$
$$= \frac{Io}{E^t.(\psi.\pi.T^2) + E^r + \frac{P(E^t+E^r)}{2} - \omega(CC))}$$
$$\times \frac{2.\left(E^t.(\psi.\pi.T^2) + E^r + \frac{P(E^t+E^r)}{2} + \frac{(E^t+E^r)P^*}{2}\right) - \omega(CC)}{I_o}$$
$$= \frac{2.\left(E^t.(\psi.\pi.T^2) + E^r + \frac{P(E^t+E^r)}{2} + \frac{(E^t+E^r)P^*}{2}\right) - \omega(CC)}{E^t.(\psi.\pi.T^2) + E^r + \frac{P(E^t+E^r)}{2}) - \omega(CC)}$$
$$= \frac{2.E^t.(\psi.\pi.T^2) + 2E^r + P(E^t + E^r) + (E^t + E^r)P^* - 2\omega(CC)}{E^t.(\psi.\pi.T^2) + E^r + \frac{P(E^t+E^r)}{2}) - \omega(CC)}$$
$$= \frac{E^t\left(2\psi.\pi.T^2 + 2.\frac{E^r}{E^t} + P(1+\frac{E^r}{E^t}) + P^*(1+\frac{E^r}{E^t}) - \frac{2\omega(CC)}{E^t}\right)}{E^t.(\psi.\pi.T^2) + E^r + \frac{P(E^t+E^r)}{2}) - \omega(CC)}$$
$$= 2.\frac{E^t\left(2\psi.\pi.T^2 + 2.\frac{E^r}{E^t} + P(1+\frac{E^r}{E^t}) + P^*(1+\frac{E^r}{E^t}) - \frac{2\omega(CC)}{E^t}\right)}{E^t\left(2.\psi.\pi.T^2 + 2.\frac{E^r}{E^t} + P(1+\frac{E^r}{E^t}) - \frac{2\omega(CC)}{E^t}\right)}$$
$$= 2 + \frac{2.P^*(1+\frac{E^r}{E^t})}{\left(2.\psi.\pi.T^2 + 2.\frac{E^r}{E^t} + P(1+\frac{E^r}{E^t}) - \frac{2\omega(CC)}{E^t}\right)}$$
$$When\ E^t >> E^r\ and\ \omega(CC)$$
$$= 2 + \frac{2.P^*}{(2.\psi.\pi.T^2 + P)}$$
$$= 2 + \frac{P^*}{p^*};\ Where,\ p^* = \left(\psi.\pi.T^2 + P/2\right)$$
$$So, Ne(life1) = Ne(life2)(2 + \frac{P^*}{p^*})$$

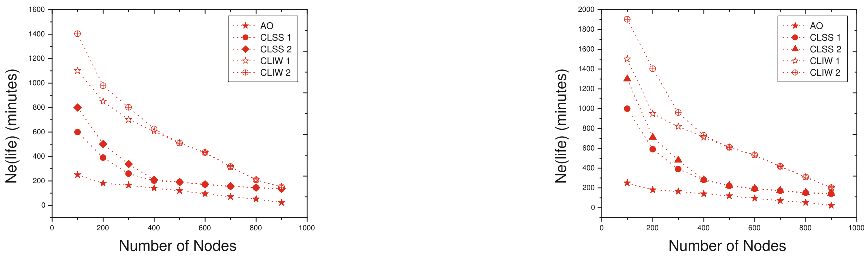
Therefore, it is clear that the network lifetime under CLIW-1 scheme is equal to the product of network lifetime of CLIW-2 and $(2 + \frac{P^*}{p^*})$.

4 Simulations

MiW was evaluated based on android operating system. Android x86 was installed on Intel I3 laptop. Samsung I997 was used for deploying the applications. We run our approach in a stand alone environment where unwanted applications are completely closed and background jobs are also shutdown. The static and dynamic power of CPU was set from 0.3 to 1 randomly and also the clock frequency was set ranging from 1.2 GHz to 1.6 GHz randomly. The energy consumption depends on the wireless connectivity i.e. the good connectivity saves more energy then the bad connectivity. The mobile phones use only one connection at a time and the first priority was given for WiFi. We used MATLAB for developing WMSNs model where network area considered was 400 × 400 m^2 and the nodes were deployed randomly ranging from 100 to 1000. The average rate of event occurs was assumed to be 35 times/minute. The initial energy of each node was set to 3.1 J. The consumption of energy during transmitting and receiving packets were set to 0.0144 mJ and 0.00576 mJ respectively. The coverage range of each cloudlet considered was 15 m and the density was set to 0.0003 per m^2. The mobile users were located at the cloudlets coverage area and the time for each mobile user located at one cloudlet range and was considered as 5 m. During this time, if a mobile user does not receive data reply from cloudlets, the mobile user sends data request from the current cloudlet to the earlier cloudlet.

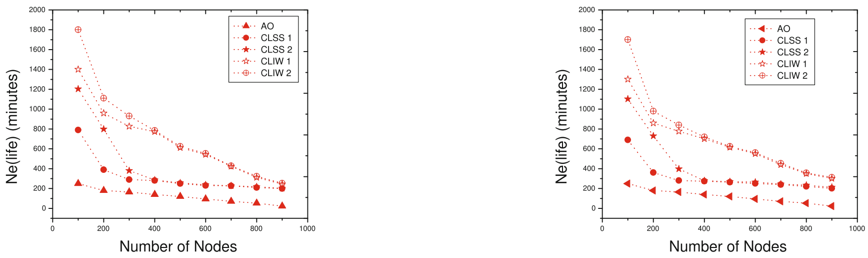
4.1 Performance Analysis

Figures 2 and 3 show the analysis of lifetime of the network of CLIW scheme and the comparison with two baselines that are *AO* and *CLSS* scheme for different mobile users. From Figs. 2 and 3, it is observed that the MCC-WMSNs integration enhances the network lifetime greatly as compared to two baselines *AO* and *CLSS* schemes. Figures 2 and 3 indicate that the network lifetime is more in case of CLIW scheme in comparison with two baselines *AO* and *CLSS* schemes. Figures 2 and 3 also indicate that the network lifetime in CLIW-1 scheme is longer as compared to CLIW-2 scheme. The proposed CLIW-2 performs better as compared to the *AO* scheme and this is because *AO* scheme considers that the sensor nodes always in the awake state where as sensor nodes maintain sleep scheduling technique in case of CLIW scheme. On the other hand, both CLIW



(a) (b)

Fig. 2. Lifetime of the network under CLIW, CLSS, and AO scheme for mobile user1 (a) and user2 (b).



(a) (b)

Fig. 3. Lifetime of the network under CLIW, CLSS, and AO scheme for mobile user3 (a) and user4 (b).

and $CLSS$ scheme consider the sleep scheduling technique but in later case the sensor nodes always depend on the location of the mobile devices. On the basis of a user request, the nodes awake and successfully respond by considering the public cloud as a middle layer. Consequently, the mobile users are able to receive sensory data through the public cloud. As compared to the sensor-cloud connectivity, the sensor nodes consume less energy when connected with the cloudlets. Proposed CLIW scheme is fully utilized when the mobile device and the sensor nodes are connected via cloudlets.

5 Conclusion

In this work, an MCC-WMSNs integration approach has been proposed which is based on the CLIW-1 and CLIW-2 scheme. The simulation results indicate that the network life time is longer in case of CLIW-1 scheme as compared to CLIW-2 scheme. The simulation results also indicate that both CLIW-1 and CLIW-2 schemes are able to prolong the network lifetime in an integrated WMSNs.

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