Selection of Optimal Path for the Communication of Multimedia Data in Internet of Things

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Abstract— The futuristic demands of multimedia applications requires an extensive exchange of complex data attributes in the context of Internet of Multimedia Things (IoMT). The exploration of the current research gap in this field shows that there is a need to develop an optimized routing technique for IoMT, which can cope-up with different network attributes, physical objects and fulfill communication requirements with cost-effective services and delivery modules. This paper proposes a cross-layer design optimization for multimedia applications in IoMT where the prime focus has been laid towards communication performance aspects such as packet delivery ratio, energy constraints and maximizing the low-cost energy utilization. The proposed employs Artificial Bee Colony (ABC) for selection of optimal path between source and destination IoT nodes. To ensure this, an extensive simulation outcome validates the performance of the proposed system.

Keywords— Internet of Multimedia Things, Cross Layer Design, Artificial Bee Colony Optimization, Swarm Intelligence, Optimal Path component

I. Introduction

The traditional desktops are transforming in to physical objects in the present internet era to utilize the advantages of IoT. The IoT combines all the surrounding physical objects in one form and offers a network to bring the communication between different devices [1] [2]. Hence various technological advancement are taking place such as radio frequency identification (RFID) and sensor network in which the communication protocol and databases are integrated to fulfil the requirements of various users [3]. The need is to accumulate data, process enormous data and then exhibit data in an effective and organized form. This demand can be achieved by IoT which, can also be considered as an extension of internet and all kinds of physical objects can interact with its assistance [4].

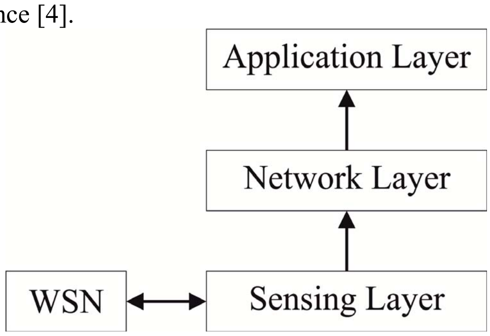

Fig. 1. Layer Approach of Communication in IoMT

The IoT environment is made up of different subsystems. These subsystems interchange data and control the system when the subsystems operate on existing infrastructure. For the design easiness, the IoT architecture is represented in three layer architecture as shown in Fig. 1. Sensor layer at the bottom sense and transfers the data to its upper layer called network layer. The network layer is to transfer the data to long range heterogeneous devices like 3G, GPRS etc and short range transmissions for Zigbee, Bluetooth etc. These data will be transmitted to uppermost application layer. The application layer will decode the messages to control the corresponding devices.

On reviewing the existing solutions towards IoMT, it is observed that:

- The existing research lacks with identifying/selecting a optimal routing path for the communication of IoMT.
- The existing research has given less empathises on QoS in IoMT.

In order to overcome these issues, a reliable cross layer model for IoMT is proposed in this work. The proposed cross layer model consist of three layers: network layer, data link layer and physical layer which contribute high heterogeneity and to exchange multimedia data the proposed model selects optimal path. The proposed integrates a ABC schema and mathematically derived a numerical computation. The concept basically mimics ABC to ensure reliable link formation between source IoT and destination IoT nodes. The contributions of the paper includes:

1) An optimized form of layered design model supporting both reliable heterogeneity and select an optimal routing path for IoMT is proposed.
2) The proposed work uses natured inspired ABC for finding an optimal route.
3) The collective intelligence of ABC swarm character is mimicked and mapped with IoMT system design.

The remaining section of the paper is discussed as follows, section II discusses related work which identifies all the major research work being done in this area. Problem statement is given in section III. Proposed system is discussed in Section IV Section V discusses about performance analysis and finally Section VI concludes the proposed work.

II. RELATED WORKS

This section presents an overview of existing research works that has been carried out in domain of routing protocol in the field of IoT.

Minimum energy consumption is considered as most prominent performance parameter for any WSNs as well as IoT applications. Liu et.al [5] have proposed A reliable and energy efficient data transmission with optimum routing protocol is introduced by for wireless networks. Also an optimal energy transmission, have derived the probability factor for encoding and decoding the data packet to attain the network coding gain. From the simulation results showed that, the proposed energy efficient routing protocol outperforms as compared to existing routing protocols with respect to minimum energy consumption. However, in the WSN environment the transmission of multimedia data is also considered as critical challenge because of data size, more energy consumption as well as bandwidth demand.

The several researchers adopted SDN based multipath routing protocols to improve the whole data center network performance and attain better results. In existing SDN based multipath routing systems, the flow allocation scheme leads to number of forwarding rules, which may lead data storage problems. By considering the pros and cons of SDN based multipath routing technology.

Pang et.al [6], have investigated a solution strategy with aim of reducing the network deployment cost and improve the storage capacity. Additionally, authors combined a multipath routing strategy with segment routing for load management to reduce the storage requirements. The simulation outcomes provides higher accuracy in terms of storage requirement and collaborative approach.

By Alvi et al. [7] to illustrate an improved version of RPL for IoMT that sensed info is fundamentally given by the multi media devices. The RPL implementation reduces carbon footprint productions and energy utilization with the integration of application precise QoS needs. To assess the performance of the proposed method a model study is focused in Cooja simulator for Contiki-OS, which shows the important gains in kind of energy effectiveness and delay.

An energy efficient multimedia communication system over IoT is widely emerging research in the green communication paradigm which mainly includes two kinds of uncertainty i.e. multimedia playout and Quality of Experience (QoE) model with different energy constraints. In the work of Zhou et.al [8] designed a green multimedia communication framework which support IoT applications. Furthermore, have developed a dynamic energy conservation policy which improves the overall system performance.

III. PROBLEM STATEMENT

The problem considered in the proposed work is to find an optimal routing path for the communication of multimedia data in IoT with the following objectives.

1) To optimize the energy consumption.
2) To increase the packet delivery ratio.

IV. PROPOSED WORK

The proposed work aims to address the energy problem of IoMT thereby it provides an integrated solution design to bridge the performance gap between services and benefits associated with IoT objects and multimedia applications. The proposed work design core methodology basically implements optimized cross layer with routing paradigm, it simulates a reliable cross-layer technique to optimize energy performance in IoMT and it further introduces ABC for energy efficient clustering to ease the routing paradigm in IoMT. The proposed system adopts the mathematical approach based methodology. The methodology adopted involves different phases covered with objectives defined. In phase one, the functions like sensing, identifying and actuating can be integrated/merged with IoT while for phase two, error free output, reliability and Energy consumption factors can be considered. During phase three of design, parameterization, and functionalists can be defined at different layers such as Physical (PH) layer, Data Link (DL) layer, and Network (NW) layer by considering frequency allocation, transmission and power modulation, error control or packet error control, fault tolerance under dynamic conditions etc. and optimized ABC clustering for routing protocol. The fourth phase of the study focuses on designing a mathematical model by considering modulation type, packet size, reliability factors etc. At the end of the study, performance analysis can be performed by considering quality of service (QoS) as performance parameter which can include delay, energy etc.

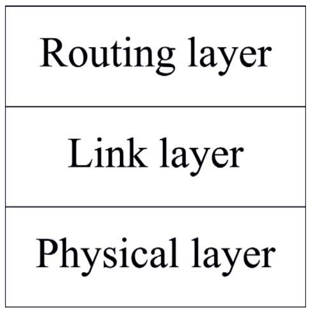

Fig. 2. Cross Layer Reference Design for IoMT

A. *Proposed Framework-Module*

The study applies optimization principle with ease of computation and numerical analysis where the prime emphasize being laid towards balancing response time *RT*, Packet error rate ER_{PKT} and the energy level *EL* which leads to minimal functional value. The study basically considers the cross-layer design module highlighted in Chong et. al [9] and further enhanced its functionality with proper modeling of different objective function formulations. In this case, the proposed work basically focuses multi-objective problem formulation for 3-set of layers associated with IoT. The mapping of objective principles can be shown by taking the reference cross-layer design into consideration. The design and analysis of the system aims to provide an optimized design solution in cross-layer protocols which can offer better communication services in terms of reliability, energy efficiency and error-free communication. The reliability of the network is achieved by considering the optimization problem solution where the optimal parameters of physical, data link and routing layers is normalized and optimized. The framework is mathematically designed in this context where the optimization is carried out considering different sort of interrelations and functionalities which are present among the layers highlighted in Fig. 2. The primary objective function can be derived as follows:

$$min\{ER_{PKT}, RT, EL\} \tag{1}$$

Three-tuple multiple objective function which can bring the solution with formulated optimal cross-layer design. The formulated design approach of IoMT is derived mathematically and also provides an insight into the cross-layer optimization paradigm. Further the optimization function $f(x)$ can be defined with respect to different optimal parameters which are multiplied with respective weight and can be mathematically expressed as follows:

$$f(x) = \min \sum \left\{ \frac{ER_{PKT}}{w1} - 1 + \frac{RT}{w2} - 1 + \frac{EL}{w3} - 1 \right\} \tag{2}$$

In Eq. (2) w1,w2,w3 represents the optimized weights. The entire numerical computation targets to compute this parameters for end-to-end communication. Further, the framework assisted module defines functionalities associated with each layer as highlighted in Fig. 2 and also formulates different parameters for communication. Algorithm 1 illustrates the steps involved in the design of cross layer model.

B. ABC based clustering

The notion of artificial bee colony (ABC) optimization from the series of bio-inspired optimization approaches has received interest from the computer science research communities to solve distributed problems of computing. The cognitive and collaborative behavior of social objects especially among the bees is popular for food searching and mating aspects. The approach of social behavior of swarm of bees towards locating their food can be correlated and mapped with the collective paradigm of IoT enabled sensor communications satisfying the constraints such as packet error rate and energy levels. Thereby this metaphor can be easily extended to the distributed networking and communication systems like IoMT which are sensor enabled and require energy effective communication in every step. The study extended its numerical modeling by means of implementing an efficient optimized ABC algorithm to ease cluster based route establishment and routing scenario in IoMT. The intelligent foregoing behavior of honey bee swarm is mimicked in this computation and the entire swarm of bees is classified into three different categories which is shown with the following Fig. 3.

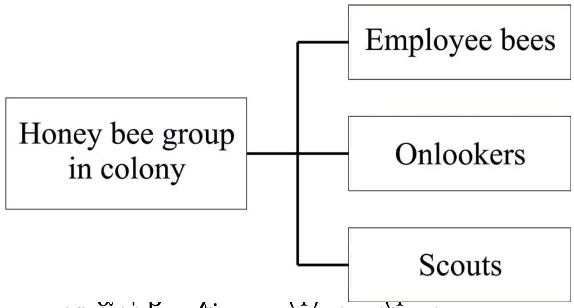

Fig. 3. Artificial honey bee swarm classification

The collective intelligence of honey bee swarm characteristic is mimicked in the IoMT system design where energy plays a very crucial role as food sources. During the deployment of IoMT communication system the cyber-physical IoT nodes are deployed initially with random pattern of distribution where the position of the food source such as energy, proximity and centrality factors are randomly generated with numerical flow of computation. During the communication phase at each round a new food source should be selected which is nearby and associated with the old one and exploited by the employed bees/CH IoT nodes $\overrightarrow{a_{mt}}$ unemployed foragers/member IoT nodes $\overrightarrow{a_{kt}}$. The nectar amount of new food source i.e. energy level, proximity for corresponding IoT CH can be computed by implementing the following mathematical expression Eq. (3).

$$\Delta_{mt} = \overrightarrow{a_{mt}} + \phi_{mt}(\overrightarrow{a_{mt}} + \overrightarrow{a_{kt}}) \tag{3}$$

Here Δ_{mt} refers to the nectar amount of food source, $\overrightarrow{a_{kt}}$ refers to unemployed foragers/member IoT and $\overrightarrow{a_{mt}}$ is the total number of bee/IoT nodes. The nectar amount of food source is directly associated with the probabilistic factors of fitness aspect.

C. Cross Layer Model Algorithm Implementation

Algorithm 1 Optimal Cross Layer Design Modeling

procedure
Input: PER_0, PER_th, time_0, time_th, Energy_0, Energy_th, P_inter
Output: Multi objective optimization
  while (1) **do**
    Deploy: IoMT in a region
    Define→Communication radius ($\in$) = 3.5 for each node Get()←T_X and R_X coordinates
    Find the nodes which are in the range of T_X dist_mat[]←compute the distance metrics between sender and its neighbor
      for (i←1:size(IoTnodes)) **do**
        if (dist≤$\in$) **then**
          Consider the T_X nodes within the range
        end if
      end for

Find the nearest node to the R_X
Formulation of functionalities at each corresponding cross layer [NW, DL, PH]
Formulate optimal route using ABC Optimized clustering Algorithm
end while
Compute→BER, Energy and End-to-End delay.
end procedure

Finally through the optimal scheduling the cost-effective route get established where it balances both delay and BER trade-offs.

V. PERFORMANCE EVALUATION

This session basically shows the experimental outcome being accomplished after simulating the i) ABC based proposed cross layer model, ii) Existing cross layer modeling [1], iii) Cross layer cluster based routing (CCBR) [10] and iv) Cross layer decision based routing protocol (CLDBRP) [10]. The algorithms are numerically modeled and implemented in MATLAB environment supported with 64 bit OS and 1.2 GHz processing clock frequency. The performance evaluation of the proposed framework has been assessed in terms of different metrics such as energy consumption and packet delivery ratio with respect to IoT nodes and distance between IoT nodes.

A. Assessment of Energy Consumption

Fig. 5 also shows that energy consumption is almost similar in the approaches of ABC, CCBR, CLDBRP, existing cross layer and the proposed cross layer optimization modeling till the network size with 50 IoT nodes but when it scaled up to 100 nodes then ABC based proposed cross layer model outperforms the other approaches. The Fig. 6 shows that even if the distance between T_X and R_X increases in proposed ABC based cross layer model, it doesn't negatively influence the energy performance and exhibits very lesser energy consumption which is quite higher in the case of other approaches. The residual energy of the network is given in Fig. 7.

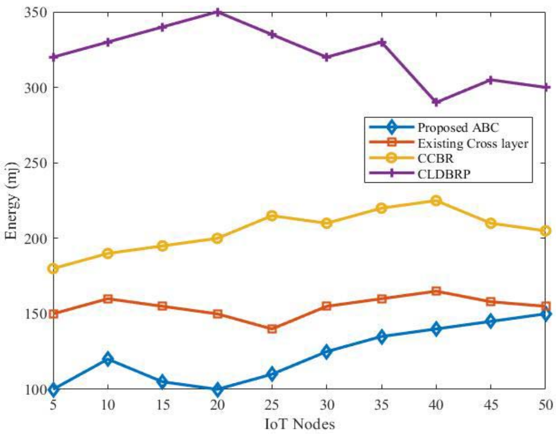

Fig. 4. Energy Consumption Assessment with respect to IoT Nodes (50 nodes)

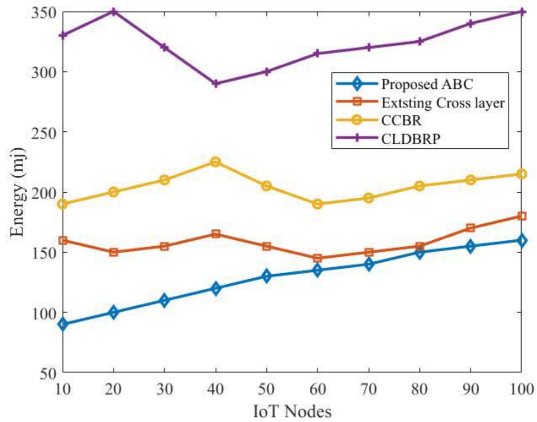

Fig. 5. Energy Consumption Assessment with respect to IoT Nodes (100 nodes)

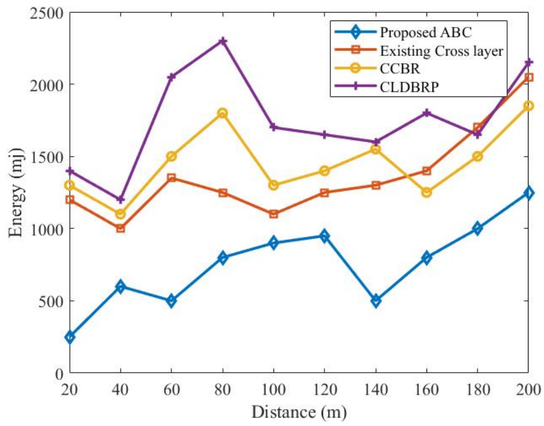

Fig. 6. Energy Consumption Assessments with respect to Distance

B. Assessment of Packet Delivery Ratio.

The packet delivery ratio of the network is shown by comparing the packet delivery ratio against the IoT nodes. Fig. 8 and Fig. 9 shows the packet delivery ratio of the network. The packet delivery ratio of the ABC based proposed cross layer model performs considerably better compared to existing cross layer, CCBR and CLDBRP approaches.

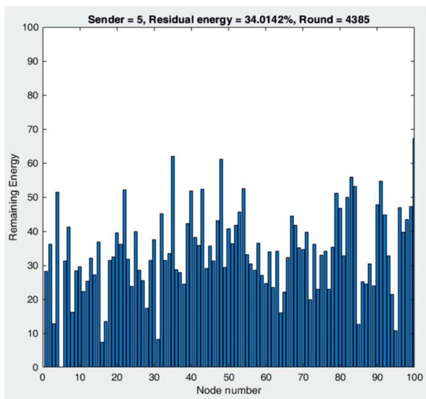

Fig. 7. Remaining Energy of the Network

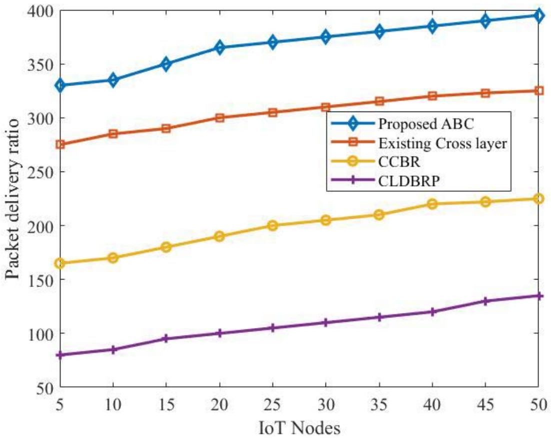

Fig. 8. Comparison of Packet Delivery Ratio with respect to IoT Nodes (50 nodes)

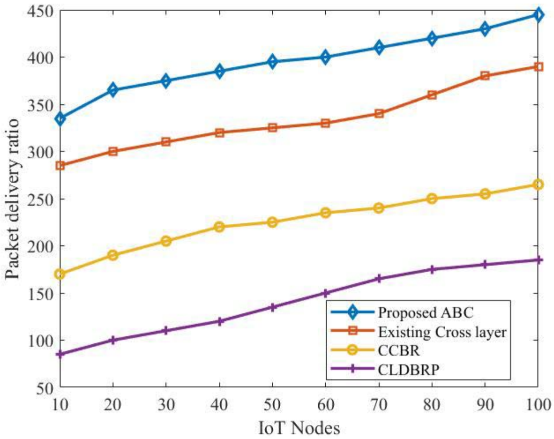

Fig. 9. Comparison of Packet Delivery Ratio with respect to IoT Nodes (100 nodes)

VI. CONCLUSION

In this work, a cross layer model for the communication of multimedia data is proposed. The proposed model supports selects an optimal path for IoMT. This work used swarm based ABC algorithm to establish reliable link formation between source and destination IoT nodes. The proposed work is implemented and evaluated using MATLAB simulation tool. The results shows 7% improvement in energy utilization and packet delivery ration increases to 8% compared to existing approaches. The obtained results ensures that the proposed ABC based cross layer model attains better communication performance and pose superiority in comparison with other baseline approaches.

In future work, The focus is to consider other QoS parameters like throughput and average delay and to evaluate it against existing approaches. The extended work need further optimization of the energy consumption and to increase packet delivery ratio by optimizing fitness function.

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