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Gravitational Search Algorithm Tuned Energy-Friendly Routing In IoT Sensors

Shivani Jindal[1], Amit Verma[2]

[1]M.Tech Scholar, Department of Computer Science and Engineering, Samalkha Group of Institutions, Samalkha, India

[2]Head of the Department, Department of Computer Science and Engineering, Samalkha Group of Institutions, Samalkha, India

ABSTRACT: Wireless networks of battery-powered sensors with an event-driven wake-up function are becoming an increasingly important application area for Internet of Things (IoT).This paper analyzes the physical relation between the power consumption and the link utilization of wireless video sensor networks. We propose a multi-channel allocation and routing method for wireless multi-hop networks where each node generates event-driven video sensor data. Routing and channel allocation put a large impact on the battery life time of IoT sensors.We realistically analyze the power consumption model for a wireless link in terms of the distance and its utilization ratio.We then present an optimization formula of utilization-aware channel allocation and routing that minimizes the overall power consumption while transferring all the required video data. We developed an efficient Gravitational Search algorithm that accurately approximates the formula. A network simulator has been developed, which show that the proposed method can reduce the overall power consumption.

KEYWORDS: Wireless video sensor network; Routing; Channel allocation; multi-hop path; Edges, Internet of Things.

I. INTRODUCTION

The Internet of Things (IoT) is what happens when ordinary everyday objects contain inter-connected microchips. Smart sensors are the building block of the IoT vision. These sensors put intelligence into everyday object turning them into smart objects that not only can collect information from the environment and interact with/control the physical world, but also be connected to each other through the internet and exchange data and information.One of the most important elements in the IoT's paradigm is wireless video sensor networks (WVSN). The research work focus on the IoT applications based on wireless video sensors network where each node is consisting of battery powered video camera sensors.These camera sensors provide video coverage over monitored regions by developing portable wireless sensors with imaging signal processing and communication capabilities. With increase in demand of surveillance applications in remote areas, wireless video cameras on battery power are increasingly deployed to cover large areas, where power lines or Internet are limited. The power source for battery recharging, however, is often limited, and thus conserving the battery power is the most important issue in IoT long term vision.

A. Background

In the past, much of research has been done in the areas of WSNs. It is, how- ever, relatively recent that WVSN has received a lot of attention. WSNs are generally assumed to carry sensor data of very low bit rate, while WVSNs usually transfer video data that is high bit rate and often real time. The goal of most WSN is to maximize the life-time of the network, or to reduce the data delivery time. Such goal becomes more challenging for WVSN due to the network properties of high data rate and real time delivery. Most of today's commercial wireless cameras use wireless networks based on Wi-Fi (IEEE802.11 standards) with an access point system operating in the infrastructure mode [7][9]. However, such wireless networks have many restrictions in their data rate, wireless range, traffic congestion, and also battery lifetime. A wireless mesh network can provide a promising solution to these prob- lems, where each camera sensor operates as a node in a mesh network. Multi- channel routing schemes can be used to reduce the RF interference and traffic congestion, and to enhance the video data rate while minimizing the power consumption [4][5][6][7].

B. Motivation

WVSN provide great insight in applications like monitoring environmental conditions or industrial plants and machinery. Because they are simple to install, they can be deployed in a multitude of situations. In coming years, we will see an explosion of new uses for wireless sensors as the ―"Internet of Things" or "IoT" is widely deployed. But one of the factors that most limits the use of wireless sensors is their limited ability to do the job for a reasonable amount of time. When a wireless sensor‘s operation is fully dependent on a battery, and the battery is depleted, it becomes just a piece of junk.
Major constraint on sensor networks used for implementing IoT is that sensors employ batteries i.e. batteries are the

driving force for the sensor nodes. Another limitation for sensors is that they are deployed unattended and in large numbers; so it becomes difficult to change or replace batteries frequently. This motivates developers and researchers to come up with such systems and communication protocols that are capable to drive these sensors for longer time with lesser power consumption.

The simplest way to increase the battery life is to use a bigger battery, a battery with higher capacity. Nevertheless, your customers are likely to expect their sensors to be small and to offer high performance (so they can send lots of data and have local intelligence/data crunching capability). Clearly, your customer expectations are diametrically opposed to the easiest way to solve the issue of short battery life.

This creates a need to find the balance between battery size and the wireless sensor‘s functionality to get the best performance from a small battery with a sufficiently long time interval between battery replacements. Thus, it becomes essential to look out for an optimized way of power-consumption in IoT sensors.

II. RELATED WORK

Research is carried out on video sensor networks where video sensor node is responsible for communicating and transferring the data via the optimized transmission path.

A. Network Structure and Assumptions

Event-driven video sensor data is generated and we assume that there is only data collection gateway called as sink node or destination node. All the active nodes capture the video data and transmit to the sink node via multi-hop routes. Following are the few primary assumptions made:

- A sensor network consists of various sensor nodes and the base stations.
- Sensor nodes are deployed in constant energy to all the nodes in the sensor field.
- Sensor nodes can estimate and control the rate at which data packets are generated. All the data packets are of the different size. In our model, data aggregation is considered.
- Sensor nodes can communicate with other sensor nodes and base stations within their radio transmission and these nodes can dynamically control their radio signal power so as to minimize the energy consumed in communication.
- Sensor nodes can estimate the energy level of their batteries at any time and estimate the energy consumed in transmitting and receiving one unit of data.
- Base stations are responsible for gathering topology information, implementing routing algorithm and distributing routing information to sensor nodes.

B. Formulation for Power Consumption and Link Utilization

This objective of this work is towards the minimization of power consumption in wireless video application of IOT. The power consumption problem has been reduced to a non linear problem with constraints [3]. The mathematical problem for this work is represented as:

$$objf = \sum P_{TX} \times UR$$

Where P_{TX} = transmitted power and UR is link utilization ratio. The Ptx and UR will be calculated between two sensor nodes termed as edge. These nodes must be alive only when any activity is detected and remaining will be in sleep mode to save power. These active nodes only take part in routing of video data to destination. This work is in support of multi hop data transmission. The choice of optimal edges satisfying the above equation is subject to constraint that

I. $e \in E$; where ‘e’ is the edge and ‘E’ is the set of all alive edges

II. The remaining link energy at each edge must be to hold the new sensor data.

Keeping these constraints into consideration, Gravitational search algorithm looks for optimal edge which consumes least power in transmission.

III. CHANNEL ALLOCATION USING GSA

A. Proposed Algorithm

GSA(Gravitational Search Algorithm**)** was introduced by Rashedi et al. in 2009 and is intended to solve optimization problems. The population-based heuristic algorithm is based on the law of gravity and mass interactions. The algorithm is comprised of collection of searcher agents that interact with each other through the gravity force. The agents are considered as objects and their performance is measured by their masses. The gravity force causes a global movement where all objects move towards other objects with heavier masses. The slow movement of heavier masses guarantees the exploitation step of the algorithm and corresponds to good solutions. The masses are actually obeying the law of gravity as shown in Equation (3.1) and the law of motion in Equation (3.2).

$$F = G\,(M1M2 / R2) \qquad 3.1$$

$$a = F/M\ (2) \qquad 3.2$$

In GSA an objective function is required which is to be minimized or maximized as per applications. In our particular case, the power consumption is to be minimized by GSA optimization and for it takes number of channels with same bandwidth of 20 MHz at the input and these are to be allocated to active nodes keeping in consideration of minimum power consumption, so optimization is required to allocate these channels to minimize path loss and effective power. The terms used in GSA algorithm has its counterpart in channel allocation problem which are tabulated in table

Table 1: Technical counterpart of bio inspired variables

	Variable in GSA	Terms in our technical concept
1	Position of agents	Bandwidth of channel allocated to each node
2	Number of dimension of searching space	Number of channels
3	Update in positions	Change in bandwidth of channel within maximum limit which is 20 MHz and 1 MHz minimum bandwidth

Each agent's position in GSA is termed as the channel allocation sequence and value of cost by objective function designed in MATLAB is calculated for each agent. The MATLAB script written for objective function calculation is in table 2. In each iteration and for each agent this function will be called in main script and a table in MATLAB will be used which save all values of minimum cost for each set of agents in every iteration. For example if there are 100 iterations and 50 agents are assumed, then initially these 50 agents will be initialized randomly or in other words the execution sequence of tasks will be assigned randomly for 1st iteration. For these 50 agents objective function value is calculated and amongst them minimum cost value is saved as best value and now these initial execution sequences will be updated using equations 3.6-3.14 and these new updated values will serve as execution sequence or agent's positions for next iterations and this process will continue till iterations last. By this way after some iteration a level will be achieved for objective function value beyond which it will not reduce. That is the conversant condition for GSA algorithm and an optimal execution sequence of tasks for our case.

B. Implementation

We have tested our results with different number of active nodes and compare the results in term of effective power and path loss component with genetic algorithm. a total of six channels are used, each of 20 MHz bandwidth and as per IEEE 802.11 standard, these channels can be used multiple times for different edges. This channel allocation process is optimised with GSA algorithm. Figure 1 shows the random placement of 9 active nodes in a geographical region of 10810 square meters with transmission range of 5 meter. 6 different channels are allocated in the network for video transmission. in this work we haven't considered the channel interference factor due to channel sharing and is left for future work.

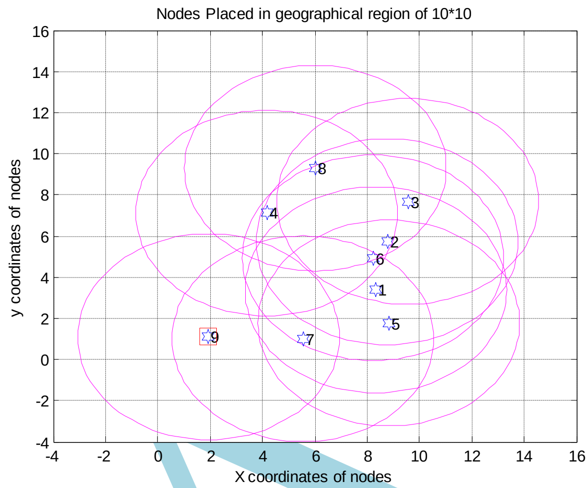


Figure 1: Randomly allocated active nodes in a geographical region of 10*10 m^2

The sink node's location is shown in red square box whereas rest nodes are shown in blue hexagon. Their transmission range is depicted by red circle for each node. Those other nodes which are inside the circle can communicate with centre node. Using the method for searching the nodes in vicinity of source node, all nodes in range are plotted. These are all possible edges for each node and shown in figure 2 using the route search algorithm which sort the all available paths on the basis of total hops and paths and pick the shortest one, finalised routes for figure 2 is shown in figure 3. A final path table for each node to sink node is shown in table 3.

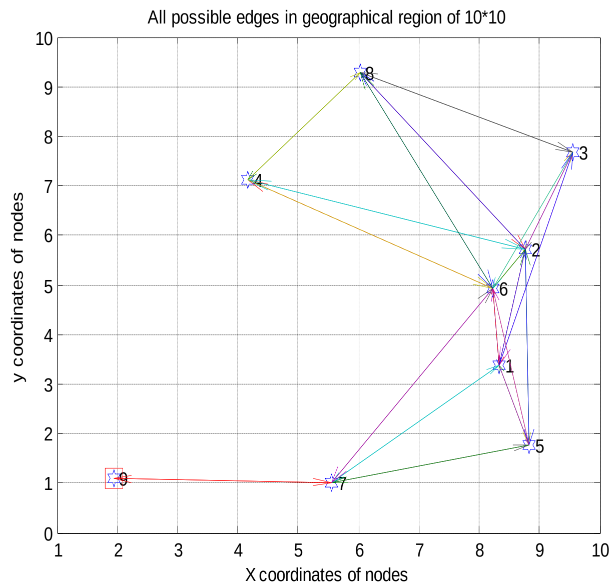


Figure 2: all possible edges for each node for nodes in figure 4.1.

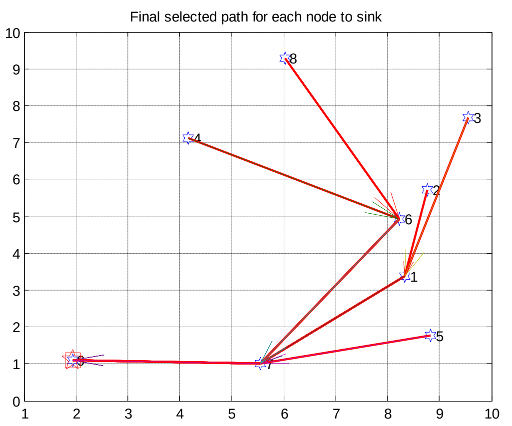


Figure 3: Finalized path for each node to sink node

Once the paths are selected then the NP hard problem of optimal allocation of channels is left, which is very important to reduce the power consumption in the network. For this we have used GSA optimization which is better than genetic algorithm (GA) search as GA is a local optimization algorithm which sometime skips local minima points during the search of minimum point whereas GSA is the global optimization algorithm which checks every point in search of global minima. Due to it the convergence rate of GSA is slower than GA but minimum point calculation in provided search space is better. Each optimization algorithm's efficiency is judges by the convergence of problem. The sooner the algorithm converges and settles to a minimum value beyond which no variation in value is observed, better is the algorithm. The comparison of convergence of GSA and GA is shown in figure 4.4 and 4.5.

Table 3: Finalized path from each node to sink for nodes in figure 4.1

1 -> 7 -> 9
2 -> 1 -> 7 -> 9
3 -> 1 -> 7 -> 9
4 -> 6 -> 7 -> 9
5 -> 7 -> 9
6 -> 7 -> 9
7 -> 9
8 -> 6 -> 7 -> 9

For GA optimisation we have used MATLAB's GA toolbox and provided the same searching space dimension and upper and lower bound for alocated channel bandwidth as GSA. if figures 4 and 5 are carefully analysed tehn we will find the scale of Peff in both cases differs a lot. This effective power is the sum of effective power in all availabe paths fo reach node to sink.

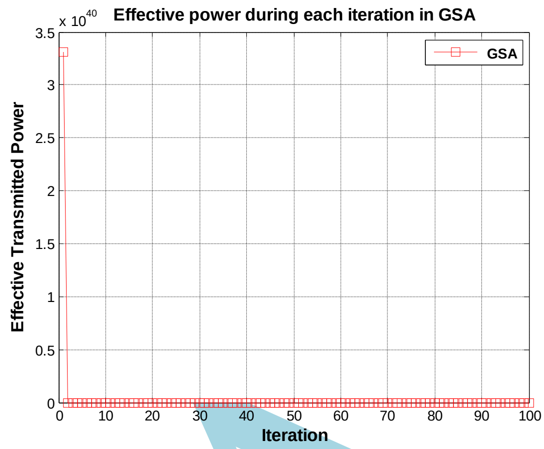


Figure 4: Fitness function value (Peff) in each iteration of GSA

After optimization the available channel bandwidth of channels allotted by both optimizations are shown in table 4.

Table 4: Optimized channel bandwidth for available channels

	Available Channel bandwidth					
GSA	20	20	20	4	4	4
GA	11	5	7	3	2	2

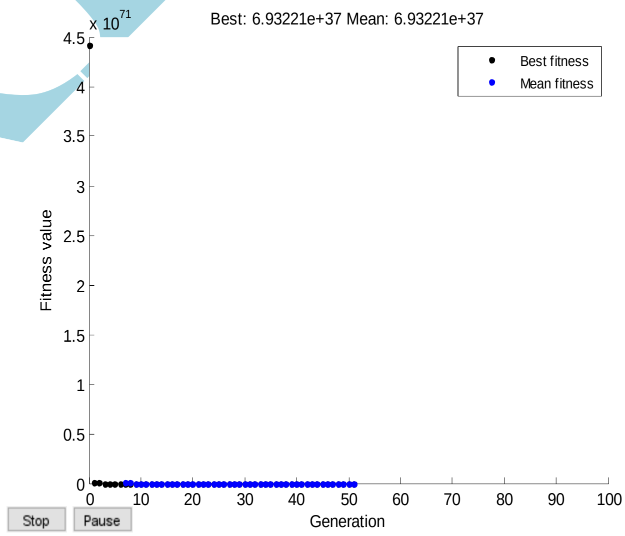


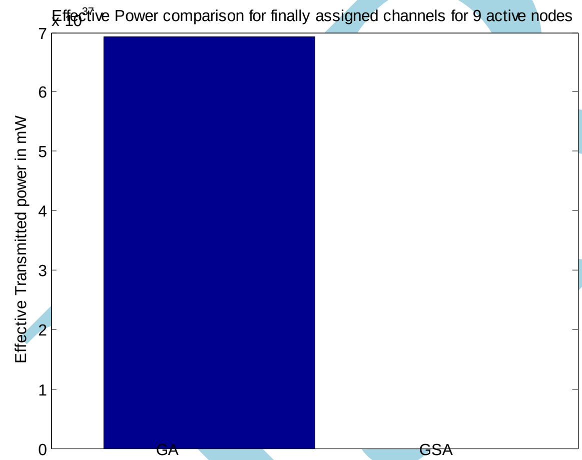
Figure 5: Fitness function value (Peff) in each iteration of GA

The comparison of total transmitted power and path loss component is shown in figure 4.6 and tabulated in 5. A large variation in transmitted power consumed in GSA is observed than GA. Similarly path loss is also less in GSA allocated channels as compared to GA. So GSA algorithm performs better than GSA and a good percentage improvement is observed. Now results are verified for different number of nodes and tabulated in 4.5.

Table 5: output parameters comparison for different number of active nodes

Active nodes →	9		20		30		40	
	GA	GSA	GA	GSA	GA	GSA	GA	GSA
Path Loss Component in dB	323.9027	122.2006	648.6279	268.6279	1.2640e+03	657.4763	3.2638e+03	1.5829e+03
Total Transmitted Power in mW	6.9322*10^37	4.0141*10^19	2.3775*10^49	2.6141*10^21	6.6962*10^62	6.7017*10^22	6.7943*10^68	6.7944*10^28

A plot for table 5 is shown in figure 7. This figure proved that with number of increase in active nodes, path loss and transmitted power consumption also increases but still with our proposed method it is still very less than genetic algorithm.



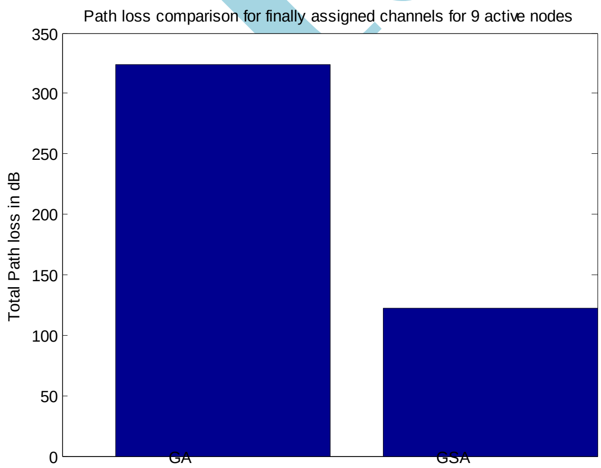
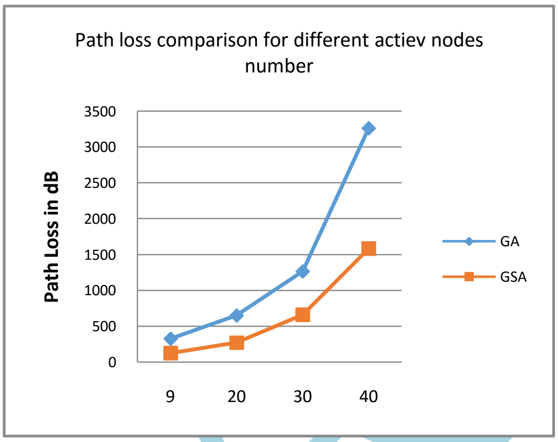
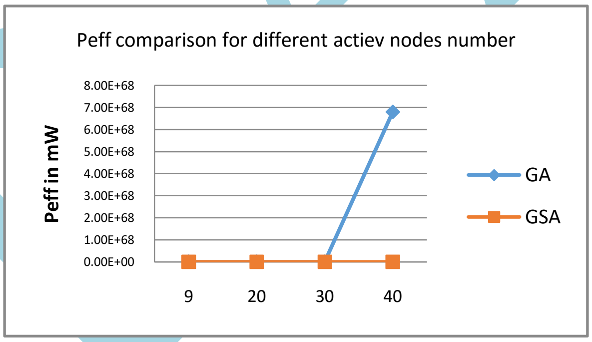


Figure 6: (a) Total transmitted power (b) Path loss component for 9 active nodes





IV CONCLUSION

One of the main challenges to the IoT is the limitation of resources, including energy supply,processing power, memory capacities, wireless communication range, and wireless communicationbandwidth. This limitation affects routing in many ways. The short wireless communication rangedictates that routing must be done in a multihop fashion, i.e., the data packets must be forwarded bymultiple relay nodes in order to reach to their destination. The low processing power and programmemory require that the routing process running on the IoT devices must be highly optimized andlight-weight. The small storage memory and scarce communication bandwidth may limit the size ofthe packets to be forwarded. The scarce energy source (either battery-supplied or harvested) makes itdifficult to decide which nodes should forward the data packets, since wireless communicationdominates the energy consumption of the IoT devices.

The solution to this is proposed by using an accurate optimizationalgorithm: Gravitational Search Algorithm (GSA). This algorithm is inspired by movement ofheavenly planets and their force of attraction.

In contrast to GSA, the genetic algorithm is quite old optimization technique and latest gravitational search algorithm is better than GA in terms of convergence. So we have updated the work with gravitational search algorithm and compared it with results of GA. The target is to minimize the power-consumption in IoT sensors used for data transmission and connectivity. An improvement of 58.59% in path loss component is achieved by GSA for 20 active nodes with same input data and total bandwidth allocated. Results have been evaluated for different number of active nodes and improvement in between 50-65% is noted for those set of active nodes. So in each aspect of observation, GSA performs better than GA and giving a less power consumption and path loss component.

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