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Comparative Performance Analysis of QC-MCSC Heuristic with Existing Heuristics over Energy Latency Density Design Space for Wireless Sensor Network

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***Abstract*-Wireless Sensor Network is a wireless network consisting of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions. In most of the cases, replenishment of batteries might be impossible. That's why lifetime of WSN shows a very strong dependency on battery lifetime. So an important issue in sensor networks is power scarcity, which depends on battery size and weight limitations of WSN node. Energy-aware algorithms are designed for extending the lifetime of wireless sensor network. For appropriate data acquisition in WSN, coverage of all targets and connectivity with the base station, both are required. Also for the reliability purpose higher order of coverage and connectivity is required.**

[1] Proposed an energy minimization heuristic called Q-Coverage Maximum Connected Set Cover (QC-MCSC). This heuristic schedules the sensor nodes activities that are having Q-coverage and connectivity requirements and thus increase the lifetime of wireless sensor network. QC-MCSC is compared with existing heuristics and a study of comparative performance of QC-MCSC and existing heuristics is done over Energy Latency Density Design Space for Wireless Sensor Network

***Keywords:*-Wireless Sensor Network, Connected Target Coverage, Network Lifetime, Network Architecture, Cover Set, Coverage, Connectivity, Q-Coverage, Connectivity.**

I. Introduction

Each node is equipped with devices which are used to monitor and collect the data, process the collected data and then transmit the data to the adjacent nodes. Finally the data is send to the base station, from which it is send to the user through the satellites or internet. Wireless sensor networks are now used in wide range of applications related to national security, surveillance, home and office application[2],habitat monitoring[3],health application [4,5], environment forecasting and military etc.

Given the vast area to be covered, the short lifespan of the battery-operated sensors and the possibility of having damaged nodes during deployment, large population of sensors are expected in most WSNs applications. Sensor node lifetime shows a very strong dependency on battery lifetime [6]. In addition, sensors in such environments are energy constrained and their batteries cannot be recharged. The nodes lose their energy quickly and become dead. The frequent topology changes due to the die of sensors make the network quite unstable.

II. Q-Coverage and P-Connectivity in WSN

Coverage is a fundamental issue in a WSN, which determines how well a phenomenon of interest (Area or target) is monitored or tracked by sensors [7, 8]. Means up to how much distance a node may sense the information. The sensing area of a sensor is normally

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assumed to be a disk with the sensor located at the center. The radius of the disk is called the sensing radius (R_s) of the sensor, up to which a sensor may cover the area.

Connectivity means the sensor network should remains connected so that the information sensed by sensor nodes can be send back to the base station. R_c (Connectivity radius) is the radius up to which a sensor may communicate its data with other sensor nodes in WSN. Connectivity is as critical as sensing coverage. Multi-hop communications are necessary when a sensor is not connected to the sink node directly. Higher order of coverage and connectivity is also required for appropriate communications up to the base station. So there is requirement of Q-Coverage and P-connectivity.

Network Lifetime is one of the most important and challenging issues in WSNs which defines how long the deployed WSN can function well. The time till the sensor network remain active and provide the information of the coverage area is called lifetime of WSN. In the absence of proper planning, the network may quickly cease to work due to the network departure or the absence of observation sensors deployed close to the interested phenomenon. Since a sensor network is usually expected to last several months without recharging [9, 10], prolonging network lifetime is one of the most important issues in wireless sensor networks.

Q-coverage: Every point in the plane is covered by at least q-different sensors [11].

P-connectivity: There are at least p disjoint paths between any two sensors [11].

III. QC- MCSC HEURISTIC

The heuristic technique called QC- MCSC [1], is given below.

INPUT (A, Q, l, E, e_1, e_2)
Set lifetime of each sensor to E.
k=0
Repeat while for each target $\Sigma_i A_{ij} B_i \geq q_j$

1) Coverage Phase

k = k + 1
$C_k = \phi$
For all targets
  Uncover_level(T) = q_i
Do while uncover_level (T)! = 0 for all targets
  Select a critical target T with uncover_level (T) > 0 and a sensor S having greatest contribution function.
  $C_k = C_k U\{S\}$
  For all targets covered by S
  Uncover_level (T) = Uncover_level (T) -1
End do

2) Connectivity and Redundancy Reduction Phase

Run the BFS algorithm and find out the shortest path from each sensor $S \in C_k$ to BS in G. Add extra nodes in this path to C_k, forming a new and updated connected set C_k.

For all $S \in C_k$

  Select a sensor $S \in C_k$ with least priority.
  If C_k - S is still a connected set cover, then
    $C_k = C_k - S$
End for

3) Energy and Priority Updation Phase

l_k = Lifetime (C_k) = Min (l,Max_lifetime (C_k))
For all $S \in C_k$
  If $S \in C_k$ is performing as only relay node
    Then $B_i = B_i - E_2$
  Else if S_i is performing as sensing node then
    $B_i = B_i - (E_1+E_2)$

  Else if $B_i < E_2$ then
    $S = S - S_i$
End for
Update priorities according to their remaining energy.

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IV. Comparison of QC-MCSC with Existing Heuristic Techniques in terms of Life Time

A small sensing area of 1000x1000m is considered in the simulation of QC-MCSC. For the simulation, the number of sensors are varied in interval [20, 150] and the number of targets in [20, 90] with an increment of 10.In figure 1, comparison of heuristic QC-MCSC is done with the other existing heuristic techniques MSC[12],HESL[13] and TPICSC[14] over the network lifetime. The graph has been drawn between the number of targets and lifetime for fixed number of sensors. In figure, the graphs depicts the quality of solution against the upper bound for l=1.00 and for fixed q_m = 1 and for different values of targets. The graph shows that the heuristic QC-MCSC achieves the lifetime higher than all existing heuristic Techniques TPICSC, HESL and MSC.

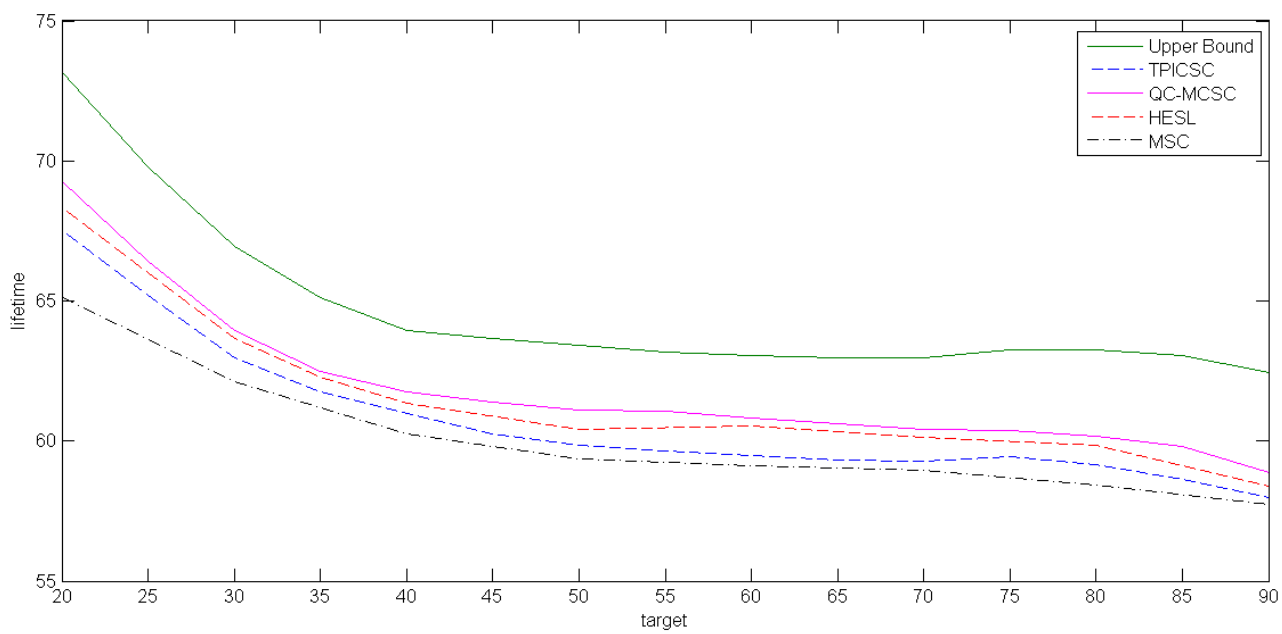

Figure 1 The Average Lifetime Obtained by QC-MCSC, HESL, TPICSC and MSC for q_m =1 & l=1

In figure 2, comparison of heuristic QC-MCSC is done with the other existing heuristic techniques MSC[12],HESL[13] and TPICSC[14] over the network lifetime. The graph has been drawn between the number of sensors and lifetime for fixed number of targets. In figure, the graphs depicts the quality of solution against the upper bound for l=1.00 and for fixed q_m = 1 and for different values of sensors. The graph shows that the heuristic QC-MCSC achieves the lifetime higher than existing heuristic Techniques HESL, TPICSC and MSC.

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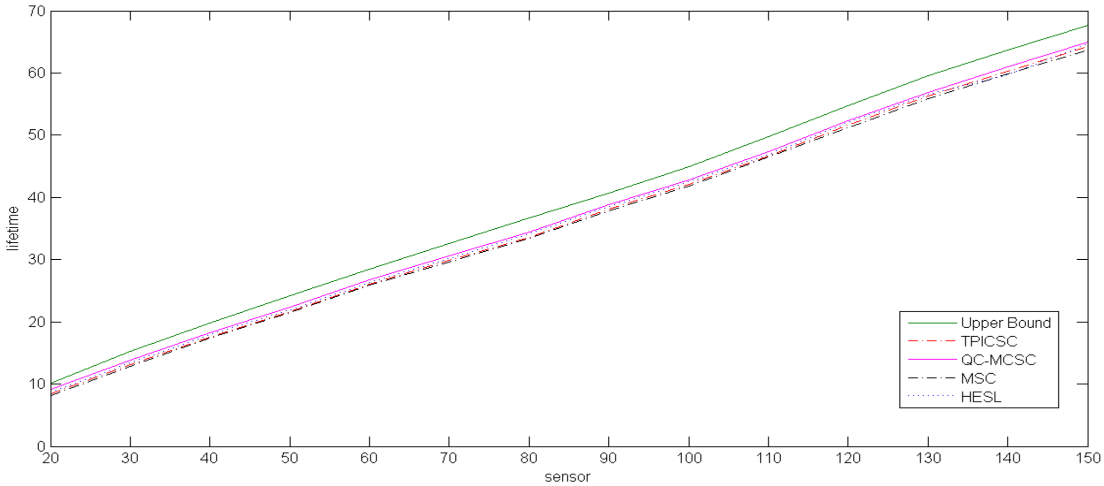

Figure 2: The Average Lifetime Obtained by QC-MCSC, HESL, TPICSC and MSC for q_m=1 & l=1.

V. Comparative Performance of QC-MCSC and Other Existing Heuristics over Energy Latency Density Design Space Model

In this research no real time application has been designed and thus no implementation of the heuristics on real time application has been done. In order to evaluate the performance of proposed Algorithm we implement the QC-MCSC Algorithm and existing algorithms over a model [15]

Energy Latency Density Design Space is a topology management application that is power efficient designed by Joseph Polastre, Jason Hill, David Culler [15]. A mathematical model of the network is designed with required energy, latency and density configuration using the model proposed by Joseph Polastre, Jason Hill, David Culler, to analyze the Performance of Proposed Heuristic in terms of Energy Efficiency and Life Time of a sensor.

The energy of a node is calculated by the overall lifetime of the nodes such as in [15]. If lifetime of the node is improved, then the total energy consumption decreases. Total energy consumed by a node is sum of the energy used in receiving (E_{rx}), transmitting (E_{tx}), listening for messages on the radio channel (E_{listen}), sampling data (E_d) and sleeping (E_{sleep}). The notations and values listed in Table 1 are used throughout in the research. Total energy used is given by

$$E = E_{rx} + E_{tx} + E_{listen} + E_d + E_{sleep} \qquad (1)$$

The energy consumed in sampling data E_d, is

$$E_d = t_d C_{data} V \qquad (2)$$

Where, $t_d = t_{data} \times r$

t_d is the time of sampling data, tdata is the sample sensors, r is the sample rate (packets/s), Cdata is the current of sample sensors (mA), V is the voltage.

The energy used in transmitting (E_{tx}) is given below. It is the length of the packet with the preamble times the packets rates,

$$E_{tx} = t_{tx} C_{txb} V \qquad (3)$$

Where, $t_{tx} = r \times (L_{preamble} + L_{packet})\ t_{txb}$

t_{tx} is the time to switch the transmitter, Lpreamble is the preamble length (bytes), L_{packet} is the packet length (bytes), t_{txb} is the time (s) to transmit 1 byte, C_{txb} is the

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current required to transmit 1 byte, V is the supply voltage.

The total energy used by receiving data (E_{rx}) is calculated by

$$E_{rx} = t_{rx} * C_{rxb} * V \quad (4)$$

Where, $t_{rx} \leq nr\,(L_{preamble} + L_{packet})\, t_{rxb}$

t_{rx} is the time (s) to switch the receiver, n is the neighborhood size of the node, t_{rxb} is the time (s) to receive 1 byte data, C_{rxb} is the current required to receive 1 byte data.

Table 1: Parameters Used for Calculations of Energy Consumption

Varibles	Parameter	Values
C_{sleep}	Sleep Current (mA)	0.033
C_{batt}	Capacity of battery	2600
V	Voltage	3.0
$L_{preamble}$	Preamble Length	271
L_{packet}	Packet Length	36
t_i	Radio Sampling	100E-3
R	Sample Rate	1/300
L	Expected Lifetime	-

The low power listening check interval called LPL interval, ti, should be less than the time of the preamble,

$L_{preamble} \geq [t_i \,/\, t_{rxb}]$

The power used in a single LPL radio sample is taken as 17.3µJ. The total energy used in listening the channel is the energy of a single channel sample multiplied by the channel sampling frequency.

$E_{sample} = 17.3\mu J$

$$t_{listen} = (t_{rinit} + t_{ron} + t_{rx/tx} + t_{sr}) * 1/t_i \quad (5)$$

$E_{listen} \leq E_{sample} * 1/t_i$

Where, t_{rinit} is the initialize radio time, t_{ron} is the turn in radio time, t_{rx}/t_x is switch to rx / tx time, t_{sr} is the time to sample radio.

The node must sleep for the rest of the time. So sleep time tsleep, is given by

$t_{sleep} = 1 - t_{rx} - t_{tx} - t_d - t_{listen}$

and

$$E_{sleep} = t_{sleep} C_{sleep} V \quad (6)$$

The lifetime of the node (T) depends on the capacity of the battery (C_{batt}) and the total energy consumed by the battery (E) and is given by:-

$$E = \frac{C_{batt} \times V}{T} \quad (7)$$

Table 2 Comparison of Performance in Terms of Energy Consumption for Existing Heuristics and QC-MCSC Heuristic over Energy Latency Density Design Space.

No. of sensor	Performance of QC-MCSC		Performance of HESL		Performance of TPICSC		Performance of MSC	
	Lifetime of sensor	Energy Consumed	Lifetime of sensor	Energy Consumed	Lifetime of sensor	Energy Consumed	Lifetime of sensor	Energy Consumed
20	9.087	0.2292652	8.763	0.237742	8.384	0.2484891	8.143	0.2558434
40	18.267	0.1140490	17.463	0.119299	17.565	0.1186070	17.376	0.1198971

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60	26.738	0.0779165	26.374	0.078991	26.038	0.0800112	25.894	0.0804562
90	38.837	0.0536430	38.537	0.054060	38.137	0.0546276	37.647	0.0553386
100	42.829	0.0486430	42.459	0.049066	42.127	0.0494536	41.727	0.0499277
120	52.283	0.0398472	51.637	0.040345	51.582	0.0403887	51.125	0.0407497
140	61.016	0.034144	59.765	0.034858	60.303	0.0345477	59.782	0.0348488

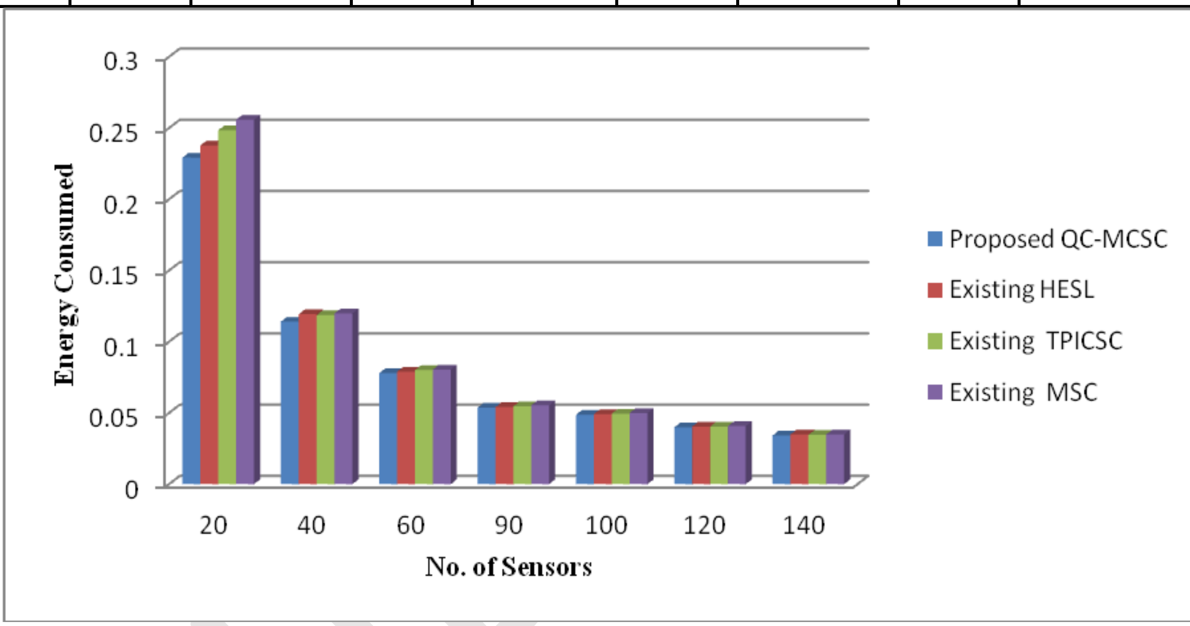

Figure 3: Comparison of Performance in Terms of Energy Consumption for Existing Heuristics and QC-MCSC Heuristic over Energy Latency Density Design Space.

The mathematical model designed for evaluation of performance quantifies the **QC-MCSC** heuristic. The above calculations, results and graphs prove that the energy consumption by the sensors in the **QC-MCSC** heuristics is less as compare to existing heuristics.

The real time implementation of the **QC-MCSC** heuristic may help in implementing low cost Wireless Sensor Networks with high efficiency.

VI. Conclusion

Heuristic called QC-MCSC is a centralized heuristic for Q-coverage and connectivity problem with QoS Requirement. QC-MCSC is based on greedy approach. In this paper, QC-MCSC is compared with TPICSC, HESL and MSC and showed that it is better than all three. The algorithm selects the critical target and the sensor with highest residual energy. One can have many variations of the problem with additional

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constraints of coverage and connectivity or directional sensing etc.

A comparative performance of QC-MCSC and existing heuristics is done over Energy Latency Density Design Space for Wireless Sensor Network. Energy Latency Density Design Space is a topology management application that is power efficient.

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