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Beaconless Color Theory Based Routing Protocol for Energy Harvesting Sensor Network

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ABSTRACT: The routing protocols designed for sensor network should be efficient in handling critical resources like energy and bandwidth to improve network lifetime. A novel Beaconless Color theory based Routing protocol (BCRP) protocol is designed which is efficient in conserving energy by reducing control packets and choosing link with higher bandwidth availability. Energy harvesting nodes are used as reference nodes whose residual energy is always sufficient for localization of other nodes in network. Color theory is adopted to localize nodes in the environment and DATA/ACK/SELECT handshake mechanism is used for packets transmission. The simulations are carried out and results are compared with Color theory based Energy Efficient Routing (CEER) protocol. The results show that performance of BCRP is better than CEER protocol.

KEYWORDS: bandwidth, beaconless, color, energy

I. INTRODUCTION

Wireless network is a network which can be deployed in an environment like military surveillances, habitat monitoring, rescue operations etc. without fixed infrastructure but with limited resources like energy, bandwidth, etc. This network can be a mobile ad hoc network or sensor network which are easy to deploy but to prolong the lifetime, smart utilization of resources are to be made. So designing a routing protocol for such a network is a challenging task. Many energy efficient routing protocols are proposed to improve the effective usage of energy resource. Energy harvesting sensor nodes are used to prolong network lifetime.

II. RELATED WORK

Minimizing energy usage by sensor nodes can be done while nodes are in active communication mode or during inactive mode. Power adjustment during data transmission and load balancing approaches are followed by different energy efficient routing protocols. Chang and Tassiulas proposed a simple and scalable routing protocol which selects minimum cost routing protocol. The efficient Minimum-Cost Bandwidth-Constrained Routing (MCBCR) protocol performs better while transmitting data from sensor nodes to base station and improves network lifetime. To balance critical resource like energy consumption, delay and bandwidth many Quality of Service (QoS) based routing protocols came into existence [1][2].

Sequential Assignment Routing (SAR) [3] protocol considers energy, QoS on each path and priority level of each packet. The main objective of SAR is to minimize average weighted QoS metric throughout the network lifetime. SPEED[4] is also QoS protocol which uses Stateless Geographic Non-Deterministic forwarding (SNFG) technique to maintain delivery speed between sensor nodes and provides end-to-end delivery guarantees.

The Spectrum-Aware BEaconless (SABE) geographical routing protocol [5] exchange request-to-forward (RTF) and accept-to-forward (ATF) packet (RTF-ATF) to select next hop forwarding node. The main weakness of this protocol is that the assumption made in the protocol that all nodes know their geographic location cannot be true due to mobility

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and to update the location is infeasible. If there is no neighbor node to forward packet, this protocol faces dead end problem. To resolve this problem, Ruhrup et al proposed Beaconless Forwarder Planarization (BFP) [6] method which selects a neighbor node closest to forwarding node which in turn relays the packet to destination, but at the cost of delay in receiving ATF packet by forwarder node. The color theory based energy efficient routing protocol [7] uses color theory for positioning and chooses an energy efficient path.

The protocols in literature survey conclude that there are protocols which route the packet in energy efficient way and few more protocols choose a protocol to improve QoS of network. In BCRP protocol, color theory is adopted to localize node and energy harvesting nodes are used as reference nodes to handle energy depletion. The protocol chooses a path for data transmission which is efficient in both energy and bandwidth availability to improve lifetime of the network.

III. Problem formulation

Designing a routing protocol for a wireless network becomes a challenging task as it includes multiple constraints is an optimization problem. Pareto and Edgeworth [8] proposed pareto optimality technique for solving multi-objective optimization problem. In general, multi-objective optimization problem can be formulated mathematically as

$$\min\left(f_1(x), f_2(x), \ldots, f_m\right) \qquad \text{eq. (1)}$$

such that $x \in C$ where $m \geq 2$ is the number of objectives and the set C is the feasible set of decision vectors.

In BCRP, two constraints namely energy utilization and bandwidth usage are considered where m = 2 and the problem can be modeled as

$$\min\left(f_1(x), f_2(x)\right) \qquad \text{eq. (2)}$$

where $f_1(x)$ is the energy optimization function and $f_2(x)$ is bandwidth optimization function. The pareto curve for two objective function $f_1(x)$ and $f_2(x)$ is shown in Fig.1.

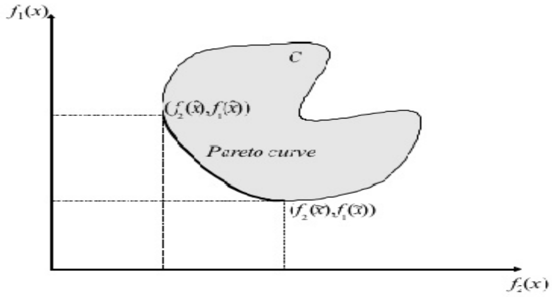

Fig.1 Pareto curve for two objective function

A. *Energy optimization*

The energy dissipation (E) during transmission of packet of size D bytes by each node is given by

$$E = E_T + E_R \qquad \text{eq. (3)}$$

$$E_T = P_T \times T_{tr} \qquad \text{eq. (4)}$$

$$E_R = P_R \times T_{rx} \qquad \text{eq. (5)}$$

where P_T, P_R transmission and reception power for transmitting D bytes of packet from a node n_i and E_T and E_R are the energy dissipation during transmission and reception of packets respectively. Due to shared nature of wireless medium, energy dissipated during transmission of a packet is modified as

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$$E = E_T + c \times E_R \quad \text{eq. (6)}$$

where c is count of nodes within transmission and interference range. The initial energy of all nodes in the network is given by E_{ini} and residual energy (E_{res}) is calculated using

$$E_{res} = E_{ini} - E \quad \text{eq. (7)}$$

The energy of path k ($E_{path}(k)$) is calculated as the minimum of energy of all nodes (n_i) within the path.

$$E_{path(k)} = \min \sum_{i=n_i}^{n_k} E_{res} \quad \forall (n_i, n_k) \in N, E_{res} \geq E_{th} \quad \text{eq. (8)}$$

where E_{th} is threshold energy of node required for successful transmission or reception.

B. *Bandwidth Considerations*

Bandwidth is the capacity of a link measured in terms of bits per second. The route with higher bandwidth may not be the best route because delay during transmission will occur due to congestion. So the bandwidth utilization should be uniform such that delay during packet transmission will be reduced. The bandwidth utilization of a node can be measured by knowing network utilization. There are various methods followed in the literature to measure network utilization using MAC layer congestion window, queue length and collision measures. Among these methods the simple one is that intermediate nodes can listen channel to track the network utilization and measure available bandwidth per second. 802.11 MAC layer is used to find free and busy times using a CSMA/CDMA through Network Allocation Vector (NAV). MAC layer can detect status of channel as busy or free. It detects the channel as busy when NAV sets a new value or receive state changes from idle to any other state and send state changes from idle to other state. It detects a free channel when NAV is less than the current time or receive state is idle or send state is idle. The bandwidth availability (B_{av}) of any node can be calculated as

$$B_{av} = B_{max} - B_u \quad \text{eq. (9)}$$

where B_{max} is initial maximum bandwidth allocated, Bu is used bandwidth of that node. The bandwidth of the selected path B_{path} is the minimum of B_{av} of all the nodes in that path.

The system architecture of the proposed protocol can be modeled as a connected directed network graph G = (N, L). N is the set of nodes {n_1, n_2, …, n_k} and L is the set of links such that L = {L_{12} , L_{21}, L_{13}, L_{31},…, L_{ij}}. L_{ij} Є L is an ordered pair (n_i, n_j), link between nodes n_i, n_j which means two way communication is possible between n_i, n_j . Let $r_i \subset N$ denotes set of reference nodes in the network {r_1, r_2, r_3, r_4} deployed in four corners of rectangular grid whose location are found using Global Positioning System (GPS). These nodes are energy harvesting nodes [9] which are able to recharge its battery from harvested energy from any environmental sources like sunlight, wind, thermal etc.

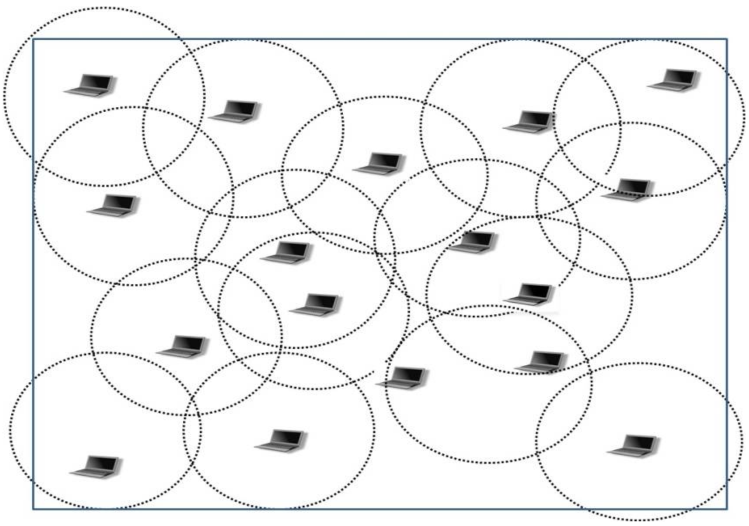

Fig. 1. Network Architecture

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The nodes in the wireless interface can be in any one of four states transmit, receive, idle or sleep mode. In reality energy consumption in each state is different, but for simplicity an assumption is made such that transmit and receive power level are equal and it is 1.4W(watts) in simulation environment. The power dissipation is less in idle state which is considered as 0.5W and no power dissipation during sleep mode.

IV. BEACONLESS COLOR THEORY BASED ROUTING PROTOCOL

The BCRP protocol consists of three modules such as setup phase, routing phase and maintenance phase. In setup phase localization of nodes in an environment are performed using color theory and Distance Vector (DV) hop approach. A location database is created which includes RGB values and associated (x,y) geographical coordinates. With the help of this information, routing of DATA packet to specified destination is performed in routing phase. The link failure due to mobility of nodes or lack of critical energy resources are handled in maintenance phase.

A. *Set up phase*

The location database maintains the geographic information of each node in the network. This is obtained using color propagation [7] and theory of mixture of colors. The building up of location data base is performed through following procedure.

The distance between node n_i and reference node r_k is calculated using

$$d_{n_i,r_k} = \sqrt{\left(x_{n_i} - x_{r_k}\right)^2 + \left(y_{n_i} - y_{r_k}\right)^2} \qquad \text{eq. (10)}$$

where $\left(x_{n_i}, y_{n_i}\right)$ and $\left(x_{r_k}, y_{r_k}\right)$ are geographical position of nodes n_i, r_k. The coordinates $\left(x_{r_k}, y_{r_k}\right)$ of reference nodes are already known and $\left(x_{n_i}, y_{n_i}\right)$ is computed using color theory and DV hop approach [10]. The RGB values of reference nodes are randomly assigned between 0 and 1. These RGB values are flooded into the network. The nodes receiving this RGB values and hop count calculates hop distance by

$$D_{n_i,r_k} = D_{avg} \times h_{n_i,r_k} \qquad \text{eq. (11)}$$

Where h_{n_i,r_k} is the hop count between nodes n_i and r_k and D_{avg}, the average hop distance based on DV hop approach. The RGB values of reference node r_k received by node n_i is converted to (HSV) using the conversion algorithm RGBtoHSV() [9]. The characteristic feature of color theory is that color fades away as distance of propagating distance which is used in conversion algorithm. The V value of HSV is decreasing proportionately as hop count value increases. This is computed as below.

$$H_{n_i,r_k} = H_{r_k}, \quad S_{n_i,r_k} = S_{r_k} \qquad \text{eq. (12)}$$

$$V_{n_i,r_k} = \left(1 - \frac{D_{n_i,r_k}}{D_{rsnge}}\right) \times V_{r_k} \qquad \text{eq. (13)}$$

The RGB of node n_i with respect to reference node r_k is calculated using algorithm HSVtoRGB()[11]. Hence RGB value of node n_i is the average RGB values of p reference nodes in the network given as RGB

$$\left(R_{n_i}, G_{n_i}, B_{n_i}\right) = \frac{1}{m} \times \sum_{p=1}^{m} \left(R_{ip}, G_{ip}, B_{ip}\right) \qquad \text{eq. (14)}$$

Similarly, for each node n_k, location information can be constructed using location database which consist of RGB values and corresponding (x,y) coordinate

B. *Routing Phase*

The beaconless color theory based routing protocol uses color theory for localizing the nodes in the network environment and route the packet to destination. Source routing is adopted in the protocol. Source node needs to transmit data packet to destination. Source node broadcast DATA packet to all its neighbors. The DATA packet format

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is {DATA, (x_s,y_s), E_{res}, B_{av}, (x_d, y_d)}. Based on this packet information neighbors will find its relative position in two regions Positive Proximity (PP) progressing towards destination and Negative Proximity (NP) which is progressing away from destination. This process of neighbor selection will help to prolong network lifetime and improve throughput. Fig. 2 illustrates the transfer of DATA packet from source to destination. The forwarding node transmits DATA packet and waits for Δt seconds. Each node receiving DATA packet is in NP ignores the DATA packet else generate ACK packet to forwarding node with its updated E_{res} and B_{av}. Source node selects ACK packet with high E_{res} and B_{av} and sends SELECT packet. The process is repeated till destination is reached.

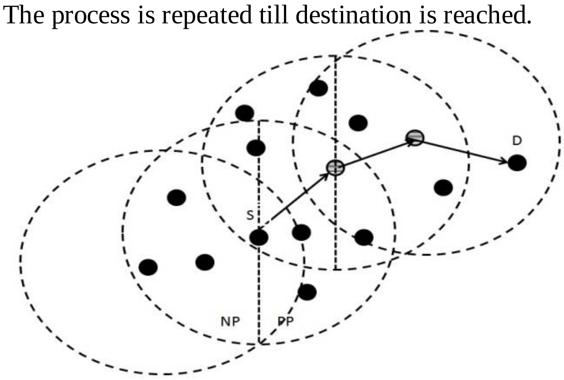

Fig. 2. Transfer of DATA packet to destination

C. *Maintenance phase*

Route maintenance phase is very important phase for highly mobile network. The routes which are found good during DATA packet transmission may not be for ACK packet transmission. The source node waits for Δt. During this period, multiple ACK packets received from multiple neighbors. Source accepts ACK packet and sends SELECT packet to neighbor with high residual energy E_{res} and B_{av}. The selected path will be a stable path but due to mobility of nodes, link failure may occur. In such situation node with next high E_{res} will be chosen by previous node for data forwarding.

V. SIMULATION RESULTS

The experiments are conducted by varying node density in topographical space of 1000 x 800 for 500 seconds. As the simulation starts, each node establishes a connection with the destination and sends packets of 512 bytes with the constant rate of 10K. The transmission range of each node is assumed to be 250m. The initial energy of all the nodes is set to be 1000J. The Drop tail queue is chosen which will discard the packet when queue is full. The simulation parameters assumed for simulation environment are shown in Table 1.

Table 1: Simulation Parameters and default values

Simulation Parameters	Values
Network Size	1000m x 1000m
Mobility Model	Random Waypoint Model
MAC Layer	802.11
Antenna Model	Omni Antenna
Queue Type	Droptail Queue
Simulation Time	400s
Node Density	50
Mobility Speed	10 m/s
Pause Time	10 µs
Network Traffic	CBR
Packet Size	512 Bytes
Transmission Range	250 m
Transmission Power	1.4w
Reception power	1.4w
Channel Bandwidth	100Mbps
Initial Energy of node	1000 Joules

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The performance of BCRP is compared with CEER. BCRP adopts color theory for positioning and it chooses neighbors with higher E_{res} and B_{av} for routing process. The performance of the protocols is compared using different metrics like energy consumption per packet, number of dead nodes, routing overhead etc.

Throughput is defined as the ratio between transmitted packets and delivered packets. BCRP generates stable path from source to destination and hence more number of packets are delivered to destination which improves throughput as shown in Fig. 3

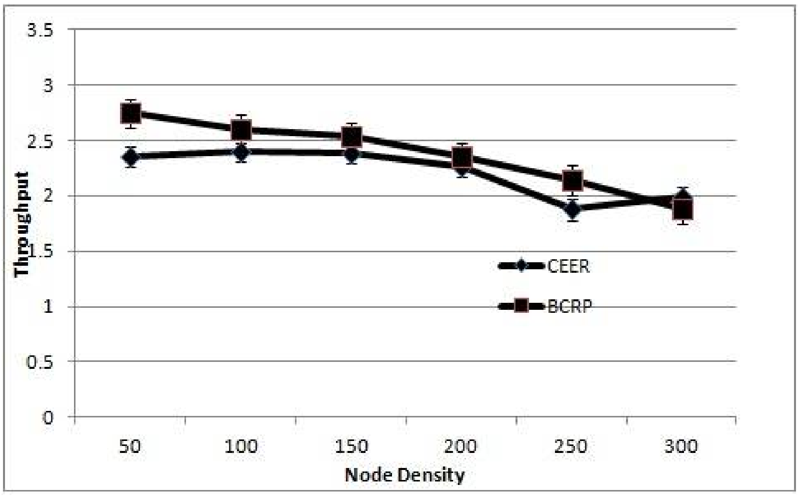

Fig. 3. Throughput varying node density

Average end-to-end delay is defined as the time taken for a data packet to be transmitted from source to destination. It includes all possible delay caused by buffering during routing, queuing at the interface queue, retransmission delay at the MAC, propagation and transfer time BCRP transmits DATA packet instead of multiple route request packet which decrease delay in transmitting original DATA packet. This mechanism of DATA/ACK/SELECT decreases delay in forwarding packet in BCRP when compared to CEER as illustrated in Fig. 4.

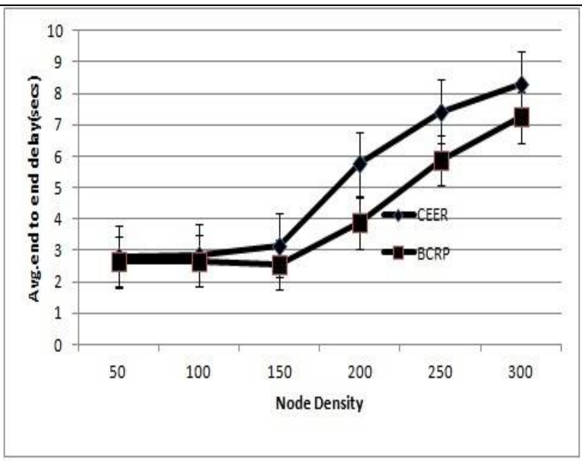

Fig. 4. Average end to end Delay varying node density

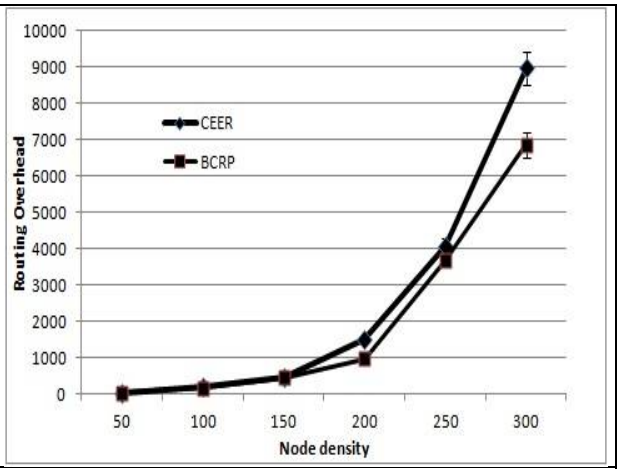

Fig. 5. Routing Overhead varying node density

Routing Overhead is the total number of control packets generated by routing protocol during the simulation. All packets sent or forwarded at network layer are considered as routing overhead. BCRP protocol chooses efficient path in terms of energy and available bandwidth which prolongs the network lifetime by reducing link failures. This reduces retransmission of same DATA and hence considerable reduction is found transfer of control packets as shown in Fig. 5.

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Total energy consumption is the sum of energy consumptions of all nodes in the network measured in milli Joules (mJ). The Fig. 6 shows that the total energy consumption of nodes in BCRP protocol less because routing packets are reduced and stable links are chosen. The route maintenance phase is also not frequently invoked which may increase energy consumption.

Number of dead nodes is the count of dead nodes at the end of simulation. The simulations are performed varying the simulation area. Dead node is a node whose energy gets drained below threshold value. When number of dead nodes increases, network lifetime will decrease. In BCRP, effective utilization of energy and balancing bandwidth availability reduces number of dead node formation as given in Fig. 7.

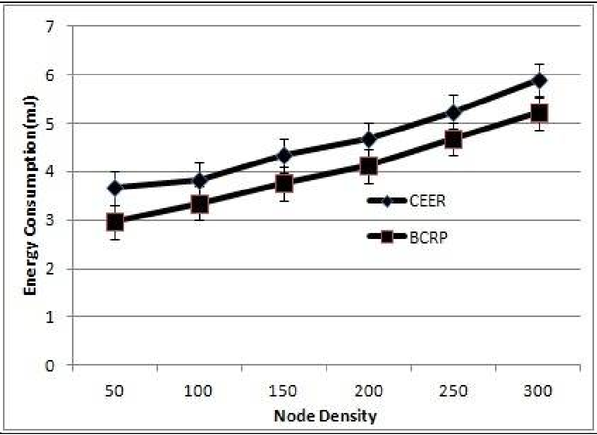

Fig. 6. Total energy consumption varying node density

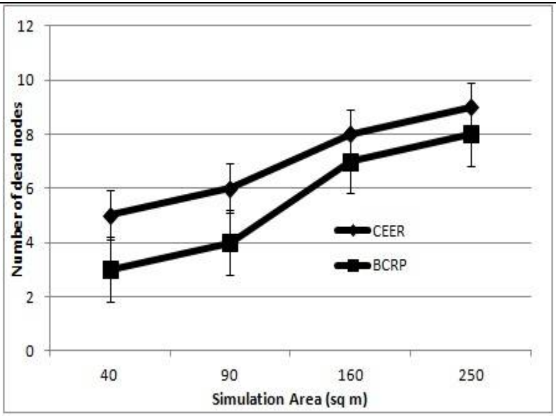

Fig. 7. Number of dead node formation varying simulation area

VI. CONCLUSION AND FUTURE WORK

The beacon less color theory based routing protocol is an efficient protocol which selects a path with high residual energy and high bandwidth availability. The protocol adopts DATA/ACK/ SELECT handshake mechanism and chooses a stable path with less number of routing overheads. The energy harvesting nodes are used as reference nodes which will prolong the network lifetime. The protocol yields better performance when compared with CEER.

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REFERENCES

1. Akkaya, K and Younis, M, 'Energy and QoS Routing for Wireless Sensor Networks', Cluster Computing , Vol. 8, Issue 2, pp. 179-188, 2005.
2. Shafiullah. G, Agyei. A and Wolfs P, 'A Survey of Energy-Efficient and QoS-Aware Routing Protocols for Wireless Sensor Networks' , Book:Novel Algorithms and Techniques, In Telecommunications, Automation and Industrial Electronics, pp. 352-357, 2008.
3. Sohrabi. K, Gao. J, Ailawadhi and Pottie, G, 'Protocols for Self Organization of a Wireless Sensor Network', IEEE Personal Communications, Vol. 7, Issue 5, pp. 16-27, 1999.
4. He.T, Stankovic. J, Lu. C and Abdelzaher, T, 'SPEED: A Stateless Protocol for Real-Time Communication in Sensor Networks', In Proc. 23rd International Conference on Distributed Computing Systems, Torodo, pp.46-55, 2003.
5. How K.C, Ma M and Qin Y, 'An Opportunistic Service Differentiation Routing Protocol for Cognitive Radio Networks', In Proceedings of the Global Telecommunications Conference, Dec. 2010.
6. Ruhrup. S, Kalosha, H., Nayak, A and Stojmenovic I, 'Message-Efficient Beaconless Georouting with Guaranteed Delivery in Wireless Sensor, Ad hoc and Actuator Networks', IEEE Transanctions. on Networking, Vol. 18, Issue 1, pp. 95-108, 2010.
7. Tai-Jung Chang , Kuochen Wang and Yi-Ling Hsieh. 'A color-theory-based energy efficient routing algorithm for mobile wireless sensor networks', Computer Networks, Vol. 52, pp. 531–541, 2008.
8. Stadler, W 'A survey of multicriteria optimization or the vector maximum problem, part I' 1776–1960, Journal of Optimization Theory and Applications, vol. 29, pp.1–52, 1979.

ISSN(Online): 2320-9801
ISSN (Print) : 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 3, March 2016

9. Jafer I, Stack. P and MacNamee, K, 'Design of New Power Management Circuit for Light Energy Harvesting System' Sensors Vol. 16, Issue 3, pp.270, 2016 doi:10.3390/s16030270.http://www.mdpi.com/1424-8220/16/3/270
10. Lin J.G. Rao. S.V, 'Mobility-enhanced positioning in ad hoc networks', In Proceedings of the IEEE Wireless Communications and Networks Conference, vol. 3, March, pp. 1832–1837, 2003
11. Vishnevsky, RGB to HSV & HSV to RGB http://www.cs.rit.edu/~ncs/color/t_convert.html.

BIOGRAPHY

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A. Sankar received his Ph.D in Computer Science from Bharathiar University, Coimbatore, India in 2003. He is currently working as an Associate Professor at the Department of Computer Applications, PSG College of Technology, Coimbatore, India. He has more than 25 years of teaching experience and ten years of research experience. His research interest includes agile software engineering, networks, e-learning and data mining.