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Capacity Maximization in Wireless Sensor Network Using CMAX Algorithm

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ABSTRACT—**Wireless sensor network deals with gathering and sending information to observer in network areas. The aim of this paper is to analyze rate and node lifetime using bandwidth. Power and rate mainly depend upon capacity of the sensor networks. An optimization framework is introduced for a multi-hop sensor network topology maximizing the information capacity sent to the sink. Sensor network capacity depends on energy adaptive mechanisms, power-bandwidth control. The capacity optimization problem is defined analytically and practical local schemes are analyzed. The performance of R_{max} and node lifetime on total bandwidth is observed. Energy dissipation of the sensor network is analyzed. CMAX algorithm is used for analyzing energy dissipation of the sensor network. Simulation result is given for the relation between data collected from sensors and available capacity when relays operating at full power by varying total bandwidth. Simulation result also show that the performance of rate and node lifetime is based on the capacity and bandwidth.**

***Index Terms*—Wireless sensor network, Capacity, Power adaptation, Capacity maximization algorithm.**

I. INTRODUCTION

A wireless sensor network (WSN) consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to a main location. The more modern networks are bi-directional, also enabling control of sensor activity.

According to federal communications commission the current static spectrum allocation has led to the overall low spectrum utilization where up to 70% of the allocation spectrum remains unused called white space at any one time even in a crowded area. Dynamic spectrum allocation has been proposed so that unlicensed spectrum users or secondary users are allowed to use the white space of licensed users or primary user spectrum with low interference with primary users. This function can be realized by implementing cognitive radio in secondary users. Cognitive radio enables cognitive radio sensor network to sense spectrum holes and to dynamically switch its parameter to available white space.
The electromagnetic radio spectrum usage is regulated under strict licensing terms resulting in significant inefficiency in spectrum utilization by the licensed primary users (PU) [1]. Dynamic and opportunistic spectrum access (OSA) as an efficient utilization mechanism allows the secondary users (SU) uses the best available channel [1], [2]. To this end, cognitive radio (CR) is proposed for effective utilization of unused bands opportunistically [3] making it possible for SUs and PUs operate in the same region by adapting the operating conditions of SUs in a manner not to disturb the normal communication standards of PUs.

II. RELATED WORK

Recently, wireless sensor network (WSN) imposing strict cost limitations on sensors has been introduced to the advantages of using nodes with CR capability, i.e. cognitive radio sensor network (CRSN). It increases the reliability of the channel used under bursty traffic, utilizes WSN in crowded spectrum bands without a license, uses adaptive power and bandwidth allocation resulting in lifetime maximization and makes heterogeneous WSN constructions possible [2].

To the best of our knowledge, there is no IT optimization study about CRSNs although some works to optimize the utilization of only a limited set of network resources. In [6], the number of spectrum handoff is reduced. Spectrum utilization and energy efficiency are improved in a multi-objective optimization with a modified game theory solution. Although spectrum allocation and transmission power are optimized, multi-hop routing, ICs and the fundamental features of CRSN, e.g., fast data aggregation, node failures and bursty data traffic, are not considered. Power consumption is reduced by optimizing modulation constellation size [7], through the minimization of energy per bit over the subcarriers [8] and optimization for application oriented source sensing, e.g., collecting information of temperature, sound, etc., and ambient-oriented channel sensing in [10]. Although lifetime and power consumption are optimized, IT metrics and multi-hop CRSN characteristics are not addressed in these works.

III. OVERVIEW OF EXISTING

Multi-hop relaying in WSNs increases the network lifetime with smaller hop distances and lower transmission power. In this article, multi-hop topology is examined with multiple sensors collecting possibly different kinds of information, and forwarding them to a sink node via relaying sensors currently not collecting data. In Table I, global constants and variables of the network model are explained and in Fig. 1(a) and (b), networking topology and its simplified version are shown.

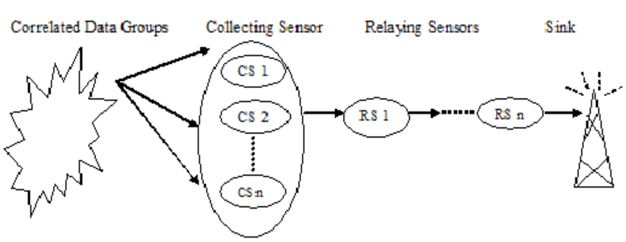

Fig.1 (a). Networking topology of multi-hop relay WSN

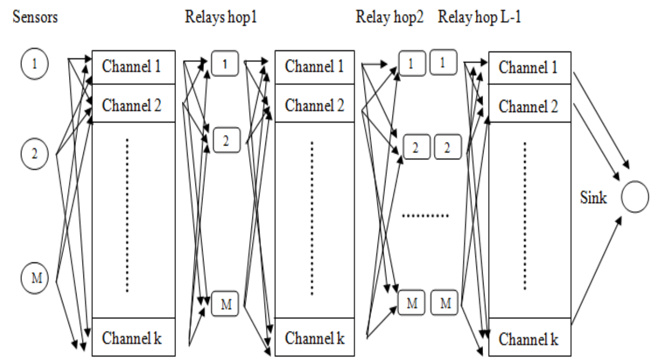

Fig.1 (b). Simplified topology

As shown in Fig. 1(a), the network is assumed to consist of two main groups of sensors, i.e., data collecting sensors and relaying sensors grouped with respect to the distance to the source and sink to simplify routing where the distance between neighboring groups is assumed to be approximately equal leading to symmetric hop levels. A more general network makes the situation complicated to observe the isolated advantages of the discussed optimizations. Besides that, a dense network topology can be assumed, e.g., it can be grouped in such node groups easily by simplifying the routing task.

Table 1 Global constants and definitions for CRSN model

Parameter	Meaning
M_s, M, L	Number of sensors, relays at a hop level and number of hop levels
T_s, t_f	Time slot interval and final duration for sink data aggregation (seconds)
$H(X_{s,j})$	Number of bits sent per time slot for the random variable $X_{s,j}$
$E_{r,m}$, $E^{i}_{r,m}(t)$	Initial and remaining energy (joule) at t, r ϵ S_3, m ϵ [1,M]

W_{Tot}	The total available bandwidth
P_{max}	Maximum transmission power

The network has Ms data collecting sensors, L-1 hop count between them and the sink, and at most M relaying sensors at each multi-hop level denoted by r.

Sensor data is received and transmitted in time slots of width Ts denoted by t^+ where t is the slot start time. In simulations, sink data is observed until a fixed final time t_f but sensors collect data until t_f for continuous traffic and until several seconds before t_f for bursty traffic.

Relays are assumed to have finite initial energies of $E_{r,m}$ where $E_{r,m}^{i}$ (t) denotes the remaining energy at times. Data collecting sensors are assumed to be capable of continuously collecting and the energy for collecting is not taken into account. Despite the importance of their energy levels, it is assumed that there is a large number of sensors continuously feeding data to multi-hop WSN and task of data collection of the failed nodes is assigned to nearby sensors.

Therefore, it becomes possible to observe the advantages of EA scheme and utilization of IC in multi-hop WSN for continuous and bursty data traffic while concentrating on data carrying. In a time slot, a transmission power P (Watts) bounded with P_{max} consumes the energy $P \times T_s$. Node failure due to finite relay lifetime is a fundamental WSN constraint and included in optimization architecture.

IV PROPOSED WORK

The aim of this paper to maintain low energy consumption for data transmission. Energy consumption can be described using CMAX algorithm. The goal of this algorithm is to lower the energy consumption required to create and to improve the lifetime of a wireless sensor network. The CMAX algorithm is explained below

The sensor network can either be in idle state or in a transmit or receive mode. We consider the energy consumed at each node when it is in a transmit or receive mode. The sensor network can be modelled as a graph G=(N,A), Where N represents the set of nodes and A is the set of edges in the network. The energy consumed for transmitting a unit message along link is represented by e_{ij}. Initial energy is denoted by E_i. Each message that has to be carried by the network has a source node that originates the message and a destination node which has to reach through the network. If the message k is transmit at node i along link then the energy at node I decreases by the quantity $l_k e_{ij}$. Steps involved in CMAX algorithm are given below.

Step 1. Consider routing message *k* on the network *G*.

Step 2. Eliminate all links (i, j) $\in$ A for which $e_{ij} > \frac{E_i(k)}{l_k}$ to form a reduced network.

Step 3. Associate weights w_{ij} with each link (i, j) in the reduced graph, where $w_{ij} = e_{ij}\left(\lambda^{\alpha_i(k)} - 1\right)$.

Step 4. Find the shortest path from s_k to d_k in the reduced graph with link weights w_{ij} , as defined in Step 3.

Step 5. Let γ_k be the length of the shortest path found in Step 3 ($\gamma_k = \infty$ if no path was found). If $\gamma_k \leq \sigma$, route the message along the shortest path, otherwise reject it.

Let messages be indexed in the order in which they are generated. Let l_k denote the length of message *k*. Let s_k and d_k represent the source and the destination nodes, respectively, of the message *k*. Let $E_i(k)$ denote the residual energy of node *i* at the time when message *k* is generated (but before it is routed). Note that according to our notation, $E_i(1) = E_i$. Let

$$\alpha_i(k) = 1 - \frac{E_i(k)}{E_i} .$$

Therefore $\alpha_i(k)$ is the fraction of the energy of node *i* that is used at the time message *k* arrives. We will refer to the quantity α_i as the energy utilization of node *i*. In the algorithm stated below, λ and σ are constants, chosen appropriately.

V PERFORMANCE ANALYSIS

Capacity is defined as the intrinsic ability of the channel to convey information; it is naturally related to the noise characteristic of the channel. The basic expression, i.e.

$$C = W \log (1 + P / (NW))$$

Where W is the bandwidth (Hz)
P is the power (Watts)
N is the noise power spectral density (Watts/Hz).

It is desired that P_{max}, W_{Tot} and noise spectral density N_0, it should be possible to transmit the total data received from 3 sensors at time j. information rates of each sensor are assumed to be equal for all sensor and time. P_{max} is chosen such that the maximum signal to noise ratio (SNR) for bandwidth is 10dB.

Capacity is the most important parameter in the sensor network. Rate, node lifetime and energy utilization are depend upon capacity. The rate is increased by varying total bandwidth due to increase the capacity of the node. The energy efficiency is reflected in node lifetime, i.e., LT, where one node gets out of energy. Node lifetime decreases as total bandwidth is increasing since as total bandwidth is increased, the capacity increases. Energy utilization is defined as the ratio of the consumed energy to the total initial energy. Total bandwidth is increased, energy utilization increases due to the increase in the capacity.

The algorithm first determines the paths that consume minimum energy and the path that maximizes minimum residual energy. Then the algorithm, through a series of shortest path computations, determines a path is good with respect to these criteria. The exponential dependence of the weight function on the energy utilization suggests that plays a dominant role in the routing. If the shortest path length is greater than a specified threshold, the message is rejected, even if there is a path with enough energy to accommodate it. Since the path length is an increasing function of time, this implies that for any particular source-destination pair, all messages will be accepted till a certain instant of time, after which all messages will be rejected. As stated earlier, without this option to reject, an adversary can inject messages that consume too many resources destroying the competitive ratio of the algorithm.

The parameters λ and σ on the performance of CMAX. We consider a network of 20 nodes located randomly in a 10×10 region. The initial energy of each node is 30 units. We assume that all messages are of unit length, and are generated randomly between all source-destination pairs. The energy required for transmitting a message along an edge (*i, j*) is max (0.001, 0.001* d_{ij}^3), where d_{ij} is the distance between nodes *i* and *j*. We assume that each node can directly send a message to every other node, and so the underlying graph is complete. We also assume that the instantaneous energy level of every node is known to all nodes. messages may be rejected even if there is sufficient energy available to route the message.

VI SIMULATION RESULT

In this section, performance vs. the total bandwidth is analyzed. Here the ratio of capacity and data rate is compared by varying the total bandwidth. Capacity is determined using the formula. The data rate is calculated for different sensor. By varying different sensors in the same time, data rate is calculated.

Table 2 Global values

Parameter	Value
M_s, M, L	3, 3, 1
$H(X_{s,j})$	11895 bits, 2200 Hz
$\sigma_S(t^+)$, $\sigma_R(r, t^+)$, $\sigma_D(t^+)$	10^{-12} (Watts/Hz)
W_{Tot}	9, 18, 27, 36, 45, 54 KHz
T_s, t_f	1,70 (sec)
P_{max}	3×10^{-8} Watts

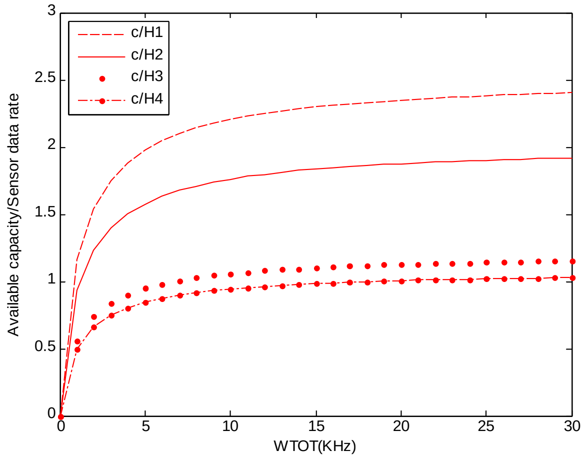

Fig.2. Ratio of available capacity for relays to the data collected from 3 sensors at time j=1 with full operating power

H1 is equal to sensor1 at a time. The ratio of capacity and data rate is high and is approximately equal to 2.4 by increasing the total bandwidth. By varying the total bandwidth, the ratio of capacity and data rate is increased exponentially. H2 is equal to sensor1 and sensor2 at a time. When compared to sensor1 the ratio of capacity and data rate is low and is approximately equal to 1.9. H3 is equal to sensor2 and sensor3 at a time. When compared to sensor1 and senor2 the ratio of capacity and data rate is low and is approximately equal to 1.2. H4 is equal to sensor1, sensor2 and sensor3 at a time. When compared to sensor2 and sensor3 the ratio of capacity and data rate is low and is approximately equal to 1.1. The performance of node lifetime and rate is compared with different mechanisms. And also compare which mechanism gives better performances.

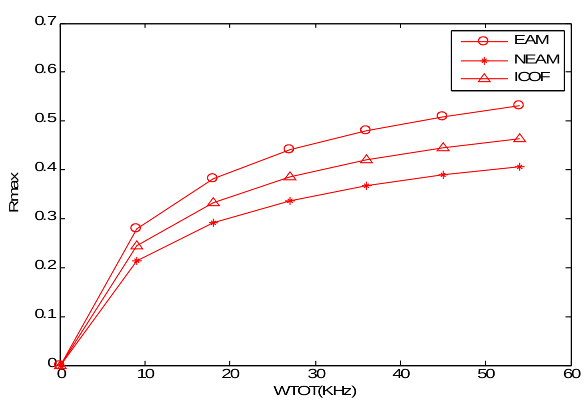

Fig.3. Performance of rate vs total bandwidth

Rmax is observed in Fig.3. The increase in Rmax with WTot is due to the increasing capacity for nodes as shown in Fig. 3. On the other hand, the saturation observed for Rmax upon an increase in WTot resembles the capacity vs. bandwidth for a single link similar to Fig. 2 and it is concluded that Rmax has roughly logarithmic bandwidth dependence like the single channel capacity expression.

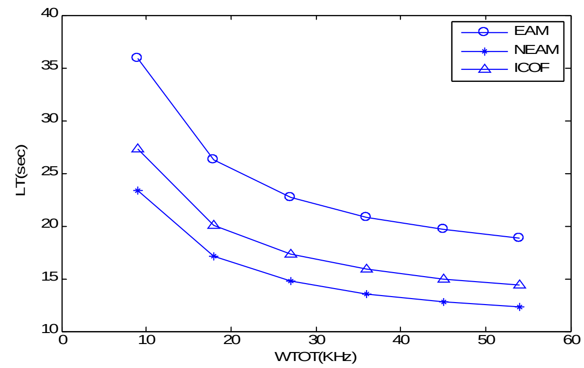

Fig.4. Performance of node lifetime vs total bandwidth

LT decreases and saturates as W_{Tot} is increased since as WTot is increased, the capacity increases and the probability to send data is increased bringing the node depletion. LT performance firstly decreases with increase in W_{Tot} since as the available bandwidth becomes larger; the nodes reach the capability to send data and to consume energy. After a higher level of increase in W_{Tot}, the nodes transmit data more probably and the expected difference due to decrease in the consumed power is not observed in saturated behavior because of the combined effect of fast depletion of nodes and the small initial node energies letting transmission of only a couple of packets preventing to observe the effect of the decrease in the power consumption.

VII CONCLUSION

Simulation result is given to the relation between data collected from sensors and available capacity when relays operating at full power by varying total bandwidth. Simulation result is given for the various performances such as rate and node lifetime. The capacity optimization problem will be defined analytically and practical local schemes will be analyzed. Rate and node lifetime are important parameter in the sensor network. Rate and node lifetime are depend upon capacity and bandwidth. When bandwidth is increased capacity and rate is increased and node lifetime is decreased due consumed energy.

REFERENCES

[1] O. Akan, O. Karli, and O. Ergul, "Cognitive radio sensor networks,"IEEE Netw., vol. 23, no. 4, pp. 34–40, July 2009.

[2] J. Mitola and G. Maguire, "Cognitive radio: making software radios more personal," IEEE Pers. Commun., vol. 6, no. 4, pp. 13–18, 1999.

[3] F. Digham, "Joint power and channel allocation for cognitive radios," in Proc. 2008 IEEE WCNC, pp. 882–887.

[4] S. Byun, I. Balasingham, and X. Liang, "Dynamic spectrum allocation in wireless cognitive sensor networks: improving fairness and energy efficiency," in Proc. 2008 IEEE VTC, pp. 1–5.

[5] S. Gao, L. Qian, D. Vaman, and Q. Qu, "Energy efficient adaptive modulation in wireless cognitive radio sensor networks," in Proc. 2007 IEEE ICC, pp. 3980–3986.

[6] S. Gao, L. Qian, and D. Vaman, "Distributed energy efficient spectrum access in wireless cognitive radio sensor networks," in Proc. 2008 IEEE WCNC, pp. 1442–47.

[7] X. Li, D. Wang, J. McNair, and J. Chen, "Residual energy aware channel assignment in cognitive radio sensor networks," in Proc. 2011 IEEE Wireless Commun. Netw. Conf., pp. 398–403.

[8] H. Zhang, Z. Zhang, X. Chen, and R. Yin, "Energy efficient joint source and channel sensing in cognitive radio sensor networks," in Proc. 2011 IEEE Int. Conf. Commun., pp. 1–6.

[9] J. A. Han, W. S. Jeon, and D. G. Jeong, “Energy-efficient channel management scheme for cognitive radio sensor networks,” IEEE Trans. Veh. Technol., vol 60, no. 4, pp. 1905–1910, 2011.

[10] G. Chung, S. Vishwanath, and C. Hwang, “On the fundamental limits of interweaved cognitive radios,” Arxiv preprint arXiv:0910.1639, 2009. Available: http://arxiv.org/abs/0910.1639v1

[11] Y. Hou, Y. Shi, and H. Sherali, “Spectrum sharing for multi-hop networking with cognitive radios,” IEEE J. Sel. Areas Commun., vol. 26, no. 1, pp. 146–155, 2008.

[12] Y. Shi, Y. Hou, H. Zhou, and S. Midkiff, “Distributed cross-layer optimization for cognitive radio networks,” IEEE Trans. Veh. Technol., vol. 59, no. 8, pp. 4058–4069, 2010.

[13] A. Burr, “Cognitive channel and power allocation: information theoretic bounds,” in Proc. 2009 IEEE CROWNCOM, pp. 1–6.

[14] D. Li, X. Dai, and H. Zhang, “Game theoretic analysis of joint rate and power control in cognitive radio networks,” in Proc. 2008 IEEE ICCCAS, pp. 319–322.

[15] V. Asghari and S. Aissa, “Rate and power adaptation for increasing spectrum efficiency in cognitive radio networks,” in Proc. 2009 IEEE ICC, pp. 1–5.

[16] A. Hoang and Y. Liang, “Maximizing spectrum utilization of cognitive radio networks using channel allocation and power control,” in Proc. 2006 IEEE VTC, pp. 1–5.