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Cognitive Radio Driven Energy Saving in Wireless Sensor Networks

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ABSTRACT

Energy saving has been one of the major design criteria for wireless sensor networks. Cognitive radio is an enabling technology for dynamic spectrum access in opportunistic manner. In the present work, we assume that wireless sensor network consists of smart radios embedded with cognitive radio capability. These smart radio nodes can sense white space available and may decide the use of channels with the best propagation characteristics. In this paper, we investigate the use of cognitive radio in wireless sensor networks which can use the frequency from white space for their operation in opportunistic manner. Cognitive radio enabled sensor nodes can adapt their system parameters according to the propagation environment. Through numerical results, we have reported that communication range available to the cognitive radio enabled sensor nodes is significantly large as compared to that available to the conventional sensor nodes. This arises due to better radio propagation characteristics. Enhanced communication range can be traded off for energy saving for the given network coverage or communication range, which ultimately leads to higher energy efficiency. Numerical results show relative energy saving on the order of 0.0055 for given system parameters.

KEYWORDS:

Cognitive Radios; Wireless Sensor Networks; Transmission Range; Energy Consumption.

I. INTRODUCTION

During the last decade, there have been extensive research and development activities both in academia and industry in the area of Wireless Sensor Networks (WSN). These networks have potential applications in habitat monitoring, environmental surveillance, civil works, and health care. These networks are battery-operated and resource-constrained. Devising the mechanisms for efficient use of non-renewable battery is an important concern for the design of WSNs. One of the major design considerations in WSNs is, therefore, their life time expectancy. Nodes in wireless sensor networks are required do both computing and communication functions. Wireless communication causes approximately 90% of the overall energy consumption. Developing energy efficient communication strategies, therefore, is an important research problem in WSNs.

There have been numerous research efforts towards minimizing the energy consumption and hence increasing their life time. Daniel p. Dallas et. al [1] have proposed a scheme to preserve energy using less number of hop counts through increased node degree.

Recently, Cognitive Radio (CR) has achieved significant attention in the research community [2-5]. It is being developed as an enabling technology to enhance spectrum utilization and spectrum efficiency. CR has the capability to learn from its surrounding environment and adapt its parameters according to the channels available in opportunistic manner.

In cognitive radio networks, unlicensed users (primary users) are allowed to use idle frequency channels opportunistically. CR enabled nodes are capable to adaptively tune their transmission parameters based on the operating environment. In the present work, we assume that wireless sensor network consists of smart radio nodes with CR capability. These smart radio nodes can sense the spectrum, identify the white space and decide to use the best possible available channel for its communication. Smart radios can adapt their operating parameters dynamically including transmitter power, operating frequency, modulation scheme and coding.

Communication range is an important system parameter in wireless sensor networks as it directly affects the energy consumption [4]. In this work, we compare the radio propagation loss in terms of the communication range available to conventional sensor nodes with that available to sensor nodes with CR capability. Numerical results are presented to demonstrate the advantage of CR in terms of increased communication range and hence the energy saving.

The rest of the paper is organized as follows: Section II describes the system model. Section III gives the analysis of the simulation results. Finally, conclusions are drawn in section IV.

2 SYSTEM MODEL

We consider a wireless sensor network comprised of smart radio sensor nodes equipped with cognitive radio capability. Link level simulation is performed in MatLab 7.0.4 for computing difference in the communication range available in ISM band that is 2.412 GHz and white space that is 980 MHz. Using channel gain at the two different channels, energy saving is computed. Sensor nodes enabled with CR capability can dynamically adapt their operating frequency. Transmission range is computed as given by Eq. (1):

$$R_i = \{c|4\pi f_i\}^2\{(P_t|P_r)\}^\gamma \ ; \quad i = 0, 1 \qquad ...(1)$$

where: $c = 3\times10^8$ m/s; f_i: operating frequency; P_t: transmit power, Pr: minimum acceptable signal strength; γ: path loss exponent

Transmission range is computed at 2.412 MHz for primary (licensed) users and at 980 MHz for secondary (unlicensed) users. It is assumed that white space is available at this frequency, which is made available to the secondary users in opportunistic manner. With a cognitive radio, secondary user (mobile station) can dynamically switch its radio to available channel in opportunistic manner.

Relative energy saving as a function of transmission power is computed as given by Eq.(2):

$$\zeta = \Delta^\gamma \rho \qquad \ldots(2)$$

where: ζ: Relative energy saving; Δ: Difference in the communication range

γ: Path loss exponent; ρ: receiver sensitivity.

3. RESULTS AND DISCUSSION

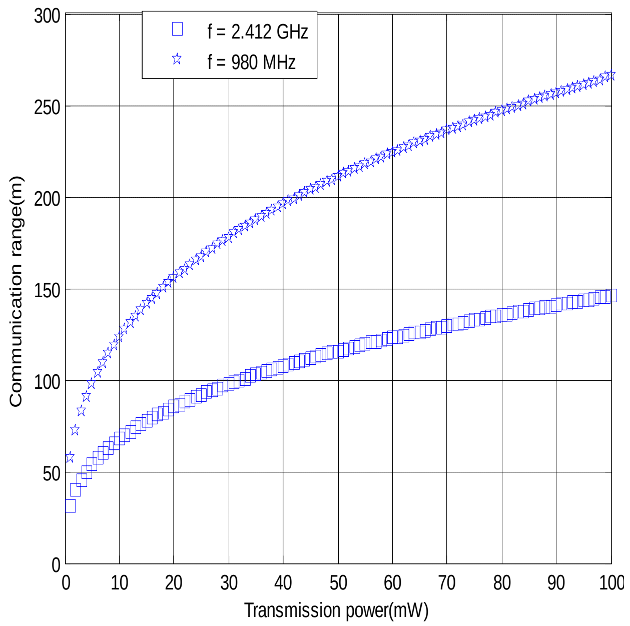
As depicted in Fig.1 (a) for path loss exponent γ = 3.0, it is observed that communication range for CR enabled nodes is significantly large as compared to that for conventional sensor nodes. Typically, for transmission power of 40 mW, the values of communication ranges for conventional and CR enabled nodes are 107 m and 196 m respectively. For transmission power of 100 mW, these values are 146 m and 266 m. The obvious reason is that lower frequency has less path loss attenuation with distance. Moreover, the difference in communication range increases with greater transmission power. In order to see the impact of radio propagation parameters, values of the communication range were also computed for another setting of path loss exponent γ = 3.5. The respective results are shown in Fig.1 (b). At greater setting of path loss exponent, signal strength decays at a faster rate and hence communication range for given transmission power is reduced. Fig.(2) shows the difference in the communication range available to both types of sensor nodes. It is observed that at higher transmission power, significantly large gain in the communication range can be obtained through CR enabled nodes.

Finally relative energy saving is plotted in the Fig. 3. It is observed that CR enabled sensor nodes can save significant energy in wireless sensor networks. As shown through different setting of the path loss exponent, it is worth to mention that energy saving is a function of radio propagation parameter, i.e., path loss exponent of the radio propagation environment.

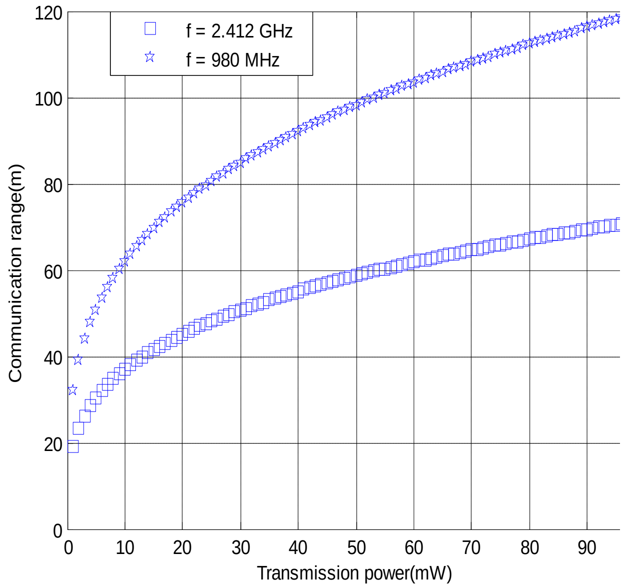
The above results establish the fact that use of CR in WSN can save the transmission power. This may be used to increase the communication range of the sensor nodes. It may further be utilized for optimization of network coverage.

4. CONCLUSION

In wireless sensor networks, power saving has been a major design criterion. In this paper, assuming that sensor nodes are equipped with CR capability, we have shown that communication range available to CR enabled sensor nodes is significantly large as compared to that available to conventional sensor nodes. This in turn may be utilized to save the energy for given network coverage or communication range. It was shown that adapting to the frequency available in white space, energy consumption can be reduced, which is an important design requirement in battery operated wireless sensor networks. The numerical results presented in the paper demonstrated the potential advantages of CR in terms of the extended network coverage and energy savings. For path loss exponent setting of 3.0 and 3.5, the relative energy saving obtained is 0.0055 and 0.0025 respectively. These features may find wide applications in wireless sensor networks. Further, we are working towards utilizing dynamic spectrum access to network coverage optimization with focus on energy saving.



(a)



(b)

Fig.1: Enhancement of communication range for (a) path loss exponent γ = 3.0 (b) path loss exponent γ = 3.5

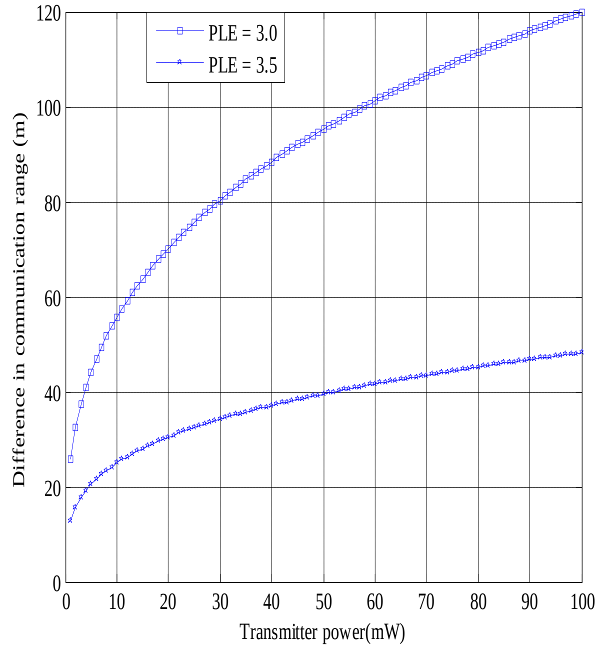


Fig. 2: Difference in communication range for conventional and CR enabled sensor nodes

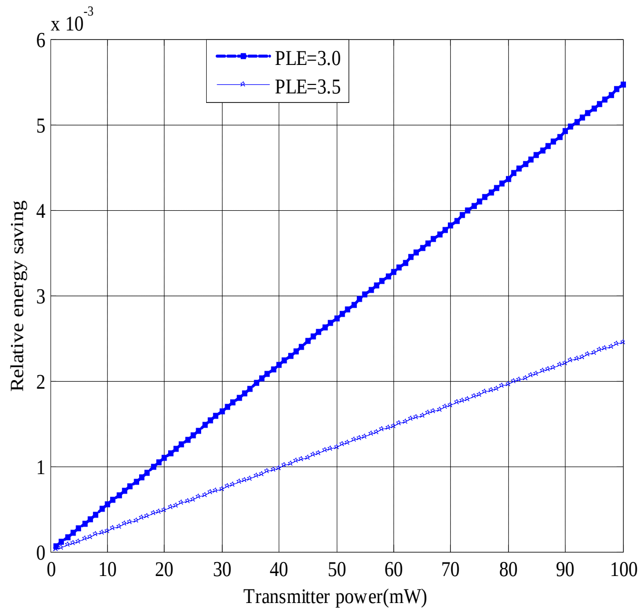


Fig. 3: Relative energy saving with cognitive radio for path loss exponent

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