Hierarchical Network Development of Wireless Passive Sensors

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***Abstract*—Design and implementation of wireless sensor systems is one of the important issues in aerospace technologies. It has wide range of applications such as monitoring different parameters in aircraft engines, satellites indoor and outdoor conditions as well as environmental data in moon and other planets in space exploration activities. In most of these applications, it is not possible to utilize active sensors due to operation failure in harsh conditions. In this article, design and implementation of a system consist of both active and passive sensors is studied.**

Index Terms- Wireless sensor network, passive sensors, surface acoustic devices.

I. INTRODUCTION

One of the main goals of space exploration is to enhance understanding of planets, origin of universe and to expand a human presence through the solar system [1]. The technologies related to development of data collection, communication and processing systems is significant part of this comprehensive chained structure. Also, data communication systems are required to control and keep track of the spacecrafts and satellites on their planned motion paths [2], [3].

In this article, we focus on the design and implementation of the wireless sensor networks to collect environmental data such as temperature, light, humidity, chemical particles density using both active and passive sensors.

II. PASSIVE SENSOR NETWORKS

In very harsh condition such as extremely high temperature, it is impossible to employ active sensors, because of the failure in operation of batteries with current technologies. One option is to use surface acoustic wave devices (SAW) as passive sensors in these systems to collect data. In a passive wireless sensor network, a signal is radiated from an interrogator system and the signal that is reflected back from a passive sensor contains information about the environment. The key point is that in SAW devices the signal is traveled in the surface of device and it experiences different delays when reflecting back from reflectors embedded on the device. The pattern of reflected signal identifies the sensor and is called RF ID. The delay between different reflected signals depends on some environmental parameters such as temperature and pressure on device and can be used as a measurand in the passive sensors [4].

Additional benefits of using passive sensors are as follows:

- Large temperature operation range

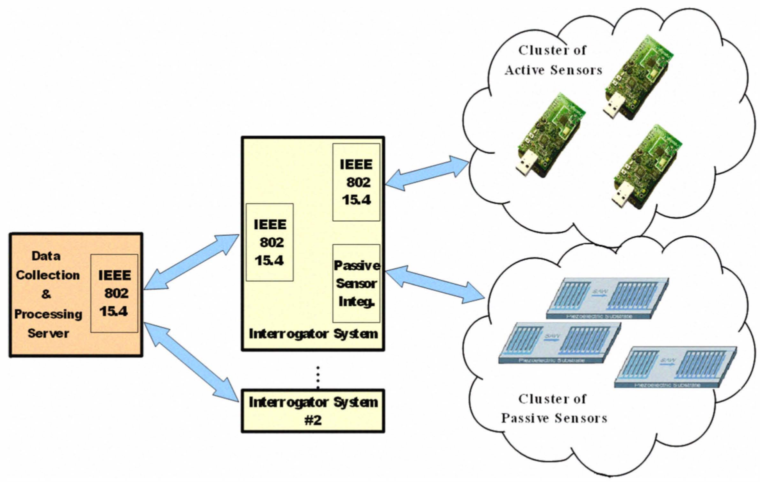

Fig. 1. System model: An Interrogator system monitors both active and passive clusters of sensors

- Wide frequency range
- Linear operation
- Low maintenance requirement
- Long life time
- Low price

Despite these advantages, one main drawback of using passive sensors is their short transmission range that is restricted to a few meters. [4]. To combat this drawback , we proposed a multi layer, sensor network consist of both passive and active nodes to extend the range and cover a larger area.

III. SYSTEM MODEL

In this project, a scenario is considered where a number of passive sensors are distributed around potential data sources in an ill conditioned environment. SAW-type passive sensors are used to detect very high or low temperatures where active sensors fail to operate. Active sensors are implemented using *TelosB TPR2400* zigbee devices. These sensors, are also placed in the locations with moderate conditions to collect other environmental parameters such as light and pressure. For instance, in an aircraft, the sensors located in the jet engine to monitor its operation should be passive type sensors, while the other sensors located in cockpit or airplane body can be of battery-powered active types. Therefore, the system consist of both passive sensor clusters and active sensor clusters. An interrogator system based on FPGA system implemented on *Xilinx Virtex4* board communicates with both passive and active sensors. A communication link is set up between interrogator system and central data management server that is equipped with the similar FPGA board. This system forms a hierarchical two layer sensor network with star configuration at each cluster which can be extended based on the application and number of data sources. The block diagram of the proposed system is depicted in Figure 1.

IV. Implementation of Communication Links

The interrogator system consist of different communication blocks. The communication link between interrogator system and passive sensors are based on Quasi orthogonal codes is developed in a joint work in Laboratory for Surface Science and Technology (LASST) and wireless sensor network (WiseNet) Laboratory in Electrical and Computer Engineering department at the University of Maine [5]. The design of communication link between interrogator system and active sensors as well as communication link between interrogator system and data collection and processing unit is studied. Since the *TelosB* devices are equipped with communication block compatible with *IEEE 802.15.4* standard, a simplified version of this protocol is chosen to be implemented in physical layer of the aforementioned communication links.

In this protocol, the data observed by sensors is digitized to form a binary sequence. The binary data sequence is then formed into 4 bit words. Each word is mapped into a binary 32-bit gold code to form chips. The chips are modulated with OQPSK and transmitted on a frequency carrier in frequency band 2400-2483.5 MHz. If R_b, R_c and R_s is bit, chip, and symbol rates, respectively, we have $8R_b = R_c = 4R_s$. The data received by the receiver is demodulated and a 32-bit Gold key is extracted. The received gold key is multiplied by each of 16 possible Gold codes and the Gold key with maximum correlation is chosen. Then the corresponding 4-bit word is chosen as the most likely transmitted word.

V. Simulation Result

The protocol is simulated in Matlab Environment using Xilinx DSP System Generator. The performance of the system is analyzed for Additive White Guassian Noise (AWGN), Rayleigh distributed and Rician distributed fading channels. Fading are assumed to be frequency flat and fading coefficients are scaled to unit energy. For Rician fading channel K factor is set to $K = \frac{m^2}{2\sigma^2} = 1$ where $m^2 = m_I^2 + m_Q^2$ is sum of square of in-phase and quadrature mean values. The simulation result in Figure 2 shows that to achieve the bit error rate as low as 10^{-3} over AWGN, Raileigh and Rician channels, the required E_b/N_0 is about $8dB$, $12dB$ and $11dB$, respectively. Because of existence of a direct path in the Rician channel it outperforms Fading channels as expected. The maximum range of communication link for passive sensors over different channel models can be determined considering maximum

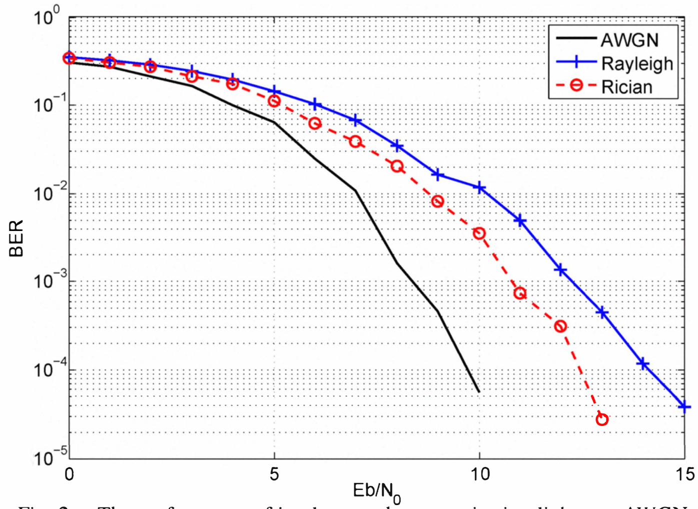

Fig. 2. The performance of implemented communication link over AWGN channel

power transmission and antenna gains. In real application due to interference effect between sensors the performance might be lower, hence sufficient power margin should be considered to guarantee the desired level of performance. For the cluster of active sensors, the signal transmitted by each of the sensors can be directly received by the central base station in addition to the copy of signal that is received via interrogator system, therefore more advanced relaying techniques can be utilized to increase the performance of system [6].

VI. Conclusion

The implementation of a hierarchical two-tier wireless sensor network is studied. Passive sensors employed to collect data from harsh condition locations and active sensors utilized to collect data from longer range locations. Due to low transmission range of passive sensors, the interrogator board should be located as close as possible to the passive sensors. The proposed star-configured system is scalable and more clusters of passive and active sensors can be added to system based on the application requirements and data distribution.

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