A WIRELESS INDUCTANCE PLETHYSMOGRAPH AS A PRECURSOR TO A NETWORKED SUITE OF LOW-POWER SENSORS FOR IN-SPACESUIT HEALTH MONITORING

Xiongjie Dong[1], Timothy Sobering[2], Thomas Barstow[3], and Steve Warren[1]
[1]Electrical & Computer Engineering, 2061 Rathbone Hall, Kansas State University, Manhattan, KS, 66506 USA
[2]Electronics Design Laboratory, 124 Burt Hall, Kansas State University, Manhattan, KS, 66506 USA
[3]Kinesiology, 1A Natatorium, Kansas State University, Manhattan, KS, 66506 USA

Networks of low-power, in-suit, wired and wireless health sensors offer the potential to track and even predict the health of astronauts engaged in extra-vehicular and in-station activities in zero- or reduced-gravity environments. Fundamental research questions exist regarding (a) the types and form factors of biomedical sensors best suited for these applications and (b) optimal ways to render these wired/wireless on-body networks given the desire to draw little-to-no power coupled with the wireless transmission challenge offered by the spacesuit itself. The work presented here begins to address each of these areas through the creation of a ZigBee wireless network of medical sensors that can be used to test new sensor prototypes and serve as a comparison baseline for lower-power custom networks that will inevitably be built into spacesuits. Drawing from prior work and lessons learned from ongoing field tests at Kansas State University (KSU), this baseline sensor network (see Fig. 1) will provide heart rate, respiration rate, acceleration/rotation, electromyograms (EMGs), and electrocardiograms (ECGs) at different body locations using various sensing techniques. Existing ZigBee-enabled pulse oximeters and accelerometer/gyroscope sensors developed at KSU (Fig. 1, right side) will be supplemented with a respiration rate sensor (Fig. 1, upper right) that employs inductive plethysmography, a technique that tracks changes in the resonant frequency of a chest belt as the chest expands and relaxes during breathing. Circuitry that provides EMGs and ECGs has already been implemented at KSU, and upgrades to these designs will utilize the same ZigBee template. Note that while inductive plethysmography has been in existence for years, the challenge in this context is to design a textile belt that can be sewn into a comfortable garment (or be defined by part of that garment) and still provide the data fidelity required for accurate respiration-rate measurements. These respiration rates can be corroborated by rate data obtained, e.g., from the baseline data present in the ECGs or the pulse oximeter photo-plethysmograms. The prototype of the belt-based respiration device depicted in Fig. 1 consists of a sensing belt, a wireless sensor module attached to the belt, and a wireless coordinator that receives data from the belt and interfaces to a computer via a USB cable. These data are visualized using MATLAB and LabVIEW. The device has demonstrated acceptable accuracy and signal-to-noise ratios in early tests, but it is a work in progress with regard to the comfort of the belt (i.e., the belt tension) versus the signal processing methods optimal to extract respiration rate from potentially noisy low-frequency data.

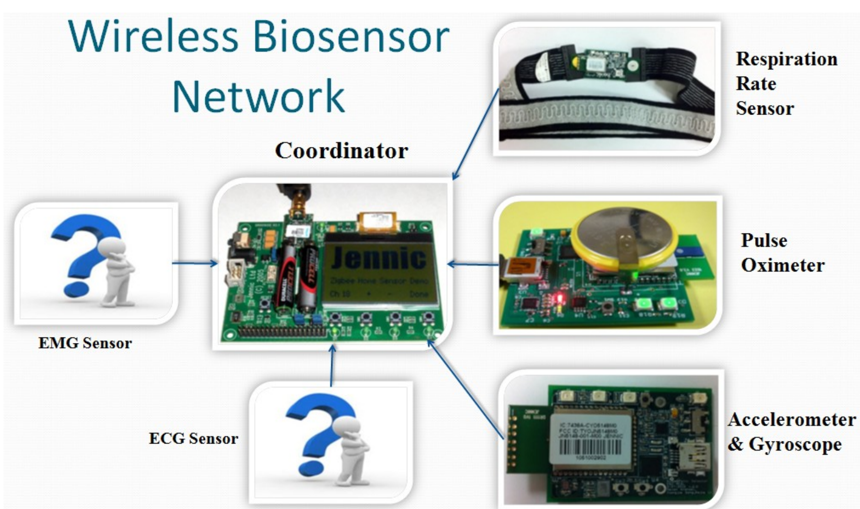

Figure 1. ZigBee network to be used as a performance baseline for upcoming device/network optimization research geared toward in-suit health sensing applications in zero- or reduced-gravity environments.