Poster Abstract: Packet Delivery Performance for On-Body Mica2dot Wireless Sensor Networks

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Abstract - **Wearable computing continues to attract researchers' interests. In particular, the combination of biomedical applications and sensor networks has been in major focus, especially in the field of real-time health care monitoring. Various connection mediums have been proposed for such platforms. This includes wired and wireless communication schemes. The inconvenience of interconnecting sensors through wires, however, not only induces high maintenance costs, but also may limits the freedom of human activity. Utilizing wireless bio-sensors nodes removes such unnatural wire constraints. Yet, employing wireless sensors in the close proximity to the human body may introduce a new set of limitations. The goal of this work is to study how the human body affects the quality of the wireless links between nodes. Unlike wire connections, wireless connections are unstable and vulnerable to noise from environment. Throughout our experiments, we attach sensor nodes to different parts of the body and monitor the packet reception rate between various nodes. We envision that the experimental results can be used to assist designers construct reliable and efficient wireless wearable computing setups for related biomedical studies.**

Index Terms – Sensor Networks, Wearable Computing.

I. INTRODUCTION

Wearable computing has long been interested by numerous research groups [2, 3, 4, 5, 6, 7, 8, 9, 20]. Some sample applications include real-time patient health care monitoring and future warrior systems. Most of the systems utilize wire interconnections to connect sensors. However, this decreases the fault tolerance of the system. With tears or punctures, the whole system may become dysfunctional or partial function. Consequently, this may yield a high maintenance cost. Furthermore, the system has to be customized for each person with respect to the physical measurements and patients' necessities.

Our main assumption is that the design of wearable computers facilitates the mass production while the flexibility to suit various necessities is not sacrificed. Furthermore, building and maintaining such system must be affordable and simplistic. We believe a wearable system should be composed of replaceable wireless sensor components that provide enough flexibility to the wearers.

Ideally, wireless sensing components are light enough to ease human movements, and they are capable of gathering vital sensory data from various bio-sensors. A data collector server node can be further attached to the waist to serve as a storage repository, gateway and/or computational unit. Vital information being monitored through bio-sensors are pre-processed by sensor nodes and transmitted to the data collector through the wireless medium.

This work presents the initial phase of our effort to build a wearable prototype system that composes wireless sensor nodes as basic sensing units. As a first step of our work, it is crucial to understand the characteristics of wireless channels in close proximity to the human body. Prior researches that study the wireless channel characteristics have conducted most of their experimental analysis inside buildings, laboratories, parking lots or habitats [10, 11, 12, 13, and 14]. This paper explores the effects of human-body on wireless communication medium. We perform our experiments with mica2dots and measure packet reception rate between every two nodes attached to the human body. Preliminary experiments results are illustrated in this paper. We expect to apply these results to design of a reliable and efficient underlying architecture supporting wireless wearable networks in future.

II. SYSTEMS

Our testbed is constructed with 433MHz mica2dot nodes [1], developed by the University of California, Berkeley and manufactured by Crossbow. The Mica2 family of sensor nodes has been widely used in sensor network related academic research fields and applied to many practical research projects. The small quarter-sized mica2dot sensor node makes it ideal for wearable applications. It has a low power microcontroller (Atmel ATmega128L [15]), and a Chipcon CC1000 RF transceiver [16]. We run TinyOS [17] on the nodes, and adapt the default CSMA based B-MAC [18] as a MAC layer protocol.

We attached eleven nodes to different parts of the human body (Figure 1), and varied the RF transmission power (Table 1) to study the relationship between packet reception rate and RF transmission power for different positions of the sensors on the body. The experiments have been carried in hallway, courtyard, and home to inspect how environments affect packets transmission. In all three environments, we examined a static standing scenario and a dynamic walking scenario to understand if body movement affects the measured quantities.

As shown in Figure 1, the antenna of a mica2dot node is flattened and circled. In mica2dots, the existence of antennas is crucial to enable the communication. However, it is unnatural and inconvenient for wearers to have sensor nodes with antennas extending outward. To seek the compromise in between, we flattened and circled the antennas. This makes easy to affix antennas to human body. We think that this antenna shape maximizes wearability factors and minimally interfere with daily activities of the wearer.

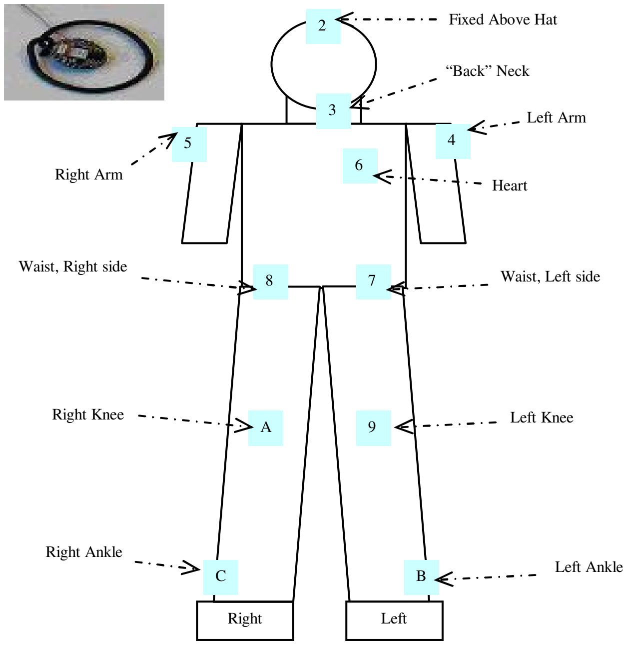

FIGURE 1. POSITIONS OF ON-BODY NODES. ANTENNA SHAPE.

Output Power [dBm]	PA_POW [hex]	Current consumption typ. [mA]
-19	0x01 (min)	6.9
-18 ~ -16	0x02	7.1
-11 ~ -12	0x04	7.6
-6	0x08	8.7
0	0x0F (default)	10.4
10	0xFF (max)	26.7

TABLE 1. SIX SELECTED RF POWER SETTINGS
(SOURCE: SMARTRF$^{®}$ CC1000 DATASHEET REV. 2.2 [16])

III. EXPERIMENT ONE – POWER SETTINGS

We conducted experiments in the following manner: (1) Node *i* broadcasts data packets at 10 pkts/sec rate with the minimum power level setting for one minute, which yields 600 transmitted packets. (2) Node *i* increases the power level according to Table 1 and then broadcasts another 600 data packets. (3) The previous procedure is repeated until node *i* reaches maximum power setting. (4) All the receiver nodes maintain recieved packet counters according to power level indicated in data field of the packet. (5) After the transmissions finish, we read back the received packet counters of every node. (6) Check the battery voltage, and replace with a new set of batteries if it is less than 2.8V. (7) Redo the experiments with another node. All nodes broadcast packets in turn with different power levels as described above. Only one node is transmitting packets at any given time and the rest serve as receivers. In a 11-by-11 node topology, there is a total number of 110 unidirectional links, excluding self-to-self links. We repeated the experiments with 6 different transmission power settings. Here we only present part of the results (Figures 2, 3) and leave the rest on the website [19] for interested readers

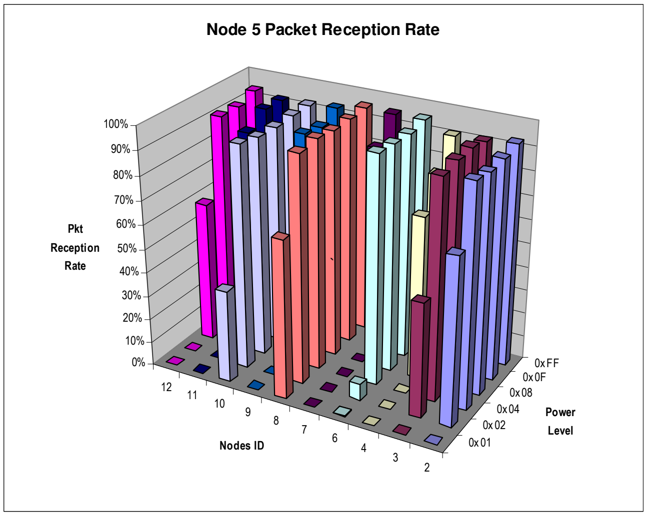

FIGURE 2. PACKET RECEPTION RATE OF NODE **5** UNDER DIFFERENT POWER SETTING, STANDING, **HOME**

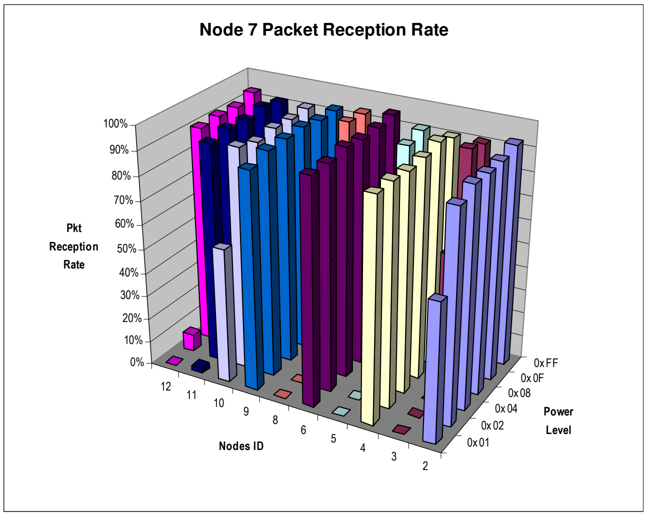

FIGURE 3. PACKETS RECEPTION RATE OF NODE **7** UNDER DIFFERENT POWER SETTING, STANDING, **HOME**

From experimental results, we observe that the packet reception rate jumps from 0% to 90% in a steep curve with a small increase in the transmission the power settings. Which may suggest it is better to fix the power setting instead to dynamically change it in order to find the optimum. This eases the protocol development and the ability of creating a system with less-overhead.

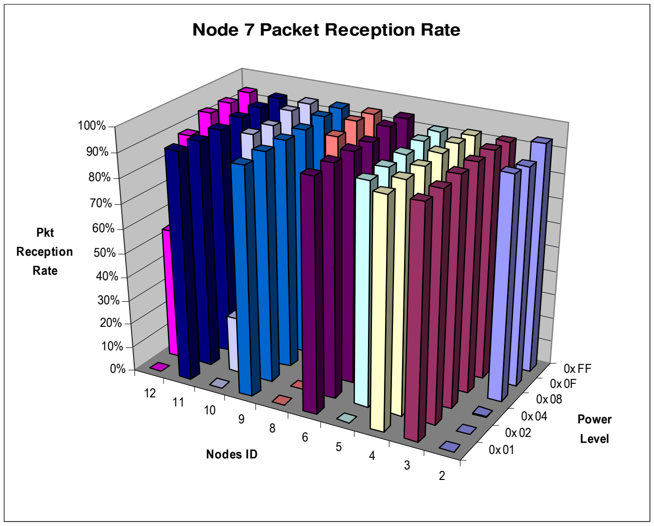

FIGURE 4. PACKET RECEPTION RATE OF NODE **7** UNDER DIFFERENT POWER SETTING, STANDING, **OUTDOOR COURTYARD**

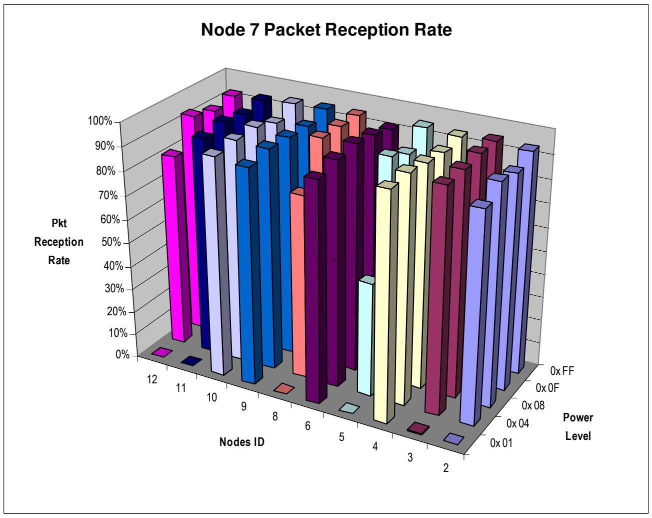

FIGURE 5. PACKET RECEPTION RATE OF NODE **7** UNDER DIFFERENT POWER SETTING, STANDING, **HALLWAY***

IV. EXPERIMENT TWO – THREE ENVIRONMENTS

Throughout the day a human moves into different environments - from home, to the car, to the office, etc. It is well-known that the wireless connection performance can significantly differ in various environments [11]. However, it is possible that sensor nodes on human body are close enough so that we can ignore these environmental factors. In order to test our hypothesis we repeated the experiments in three different environments, home (Figure 3), courtyard (Figure 4), and hallway (Figure 5) to explore how the wireless channel behaves in these environments. Comparing results from three graphs, some nodes have stable links between node 7 in all three environments, examples as node 4, 6, and 9. Some links are affected by different environments, such as node 5 and 10 to node 7. This exposes a possible necessity of a dynamic algorithm for finding the stable and efficient operating point for each link at different environment.

V. CONCLUSION

Due to space limitation, the experimental results for the walking scenarios are not presented in this paper and are available at [19]. Observing the collected data sets, we presume that the behavior of wireless channels on human body has highly temporal correlations. We plan to expand our studies to discover if environment or behavior dominates this phenomenon.

Our experiments collected more than 274,000 packets in total, and we explored the packet delivery performance of the wireless communication between on-body sensor nodes. The results can be utilized by designers to implement a more reliable and efficient wireless wearable network while still saving in power in sensor nodes.

VI. REFERENCES

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