12.12.2006

A Wireless Body Area Sensor Network for Posture Detection

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Abstract: *The upcoming technology of Body Area Sensor Networks (BASN) has potential to enabling the design of Human Computer Interfaces (HCI). This type of applications poses new design challenges that are hard to be faced using traditional solutions. This paper present a novel solution for wireless and wearable posture recognition based on a custom-designed wireless body area sensor network, called WiMoCA. These nodes which are mounted on different parts of the human body make use of tri-axial accelerometers to detect body postures.*

1. Introduction

This paper presents the first complete implementation of a distributed posture recognition application based on a custom-designed wireless body area sensor network, using WiMoCA (wireless sensor node for a Motion Capture system with Accelerometers).

2. System Architecture

The system consists of two main components, one is the WiMoCA node and the other is the Gateway Node.

2.1 WiMoCA Node:

The node is equipped with three accelerometers aligned at three perpendicular axes. Its structure is modular and it is easily compos able. The main parts of it are battery, the sensors, microcontroller transceiver. It consists of "on the shelf" components and is very cheep. Also the size is considerabley small. Its dimentions are 20x20x18 mm.[1]

Figure 1: WiMoCA node

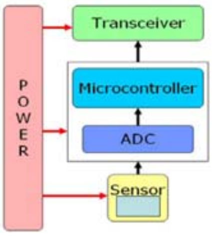


Figure 2: block diagram of node structure

2.2 The Gateway Node:

The gateway node is the central device for the network. It handles the communication and transmission of data and instructions from and to the nodes.

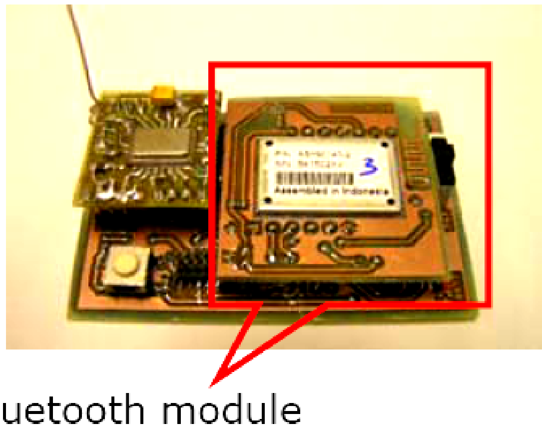


Figure 3: The Gateway node

The radio of gateway node works on Bluetooth technology. The Bluetooth module is interchangeable with serial cable connection of Ethernet connection modules. [1]

2.3 System structure:

Network is organized with a star topology. WiMoCA nodes are end-points of the star and they are responsible for sensing and acquiring data from the environment before sending them to the gateway node. The gateway performs bridging functions and has no sensing device. Coordination among transmissions of various nodes to the gateway is performed at MAC-level. [2]

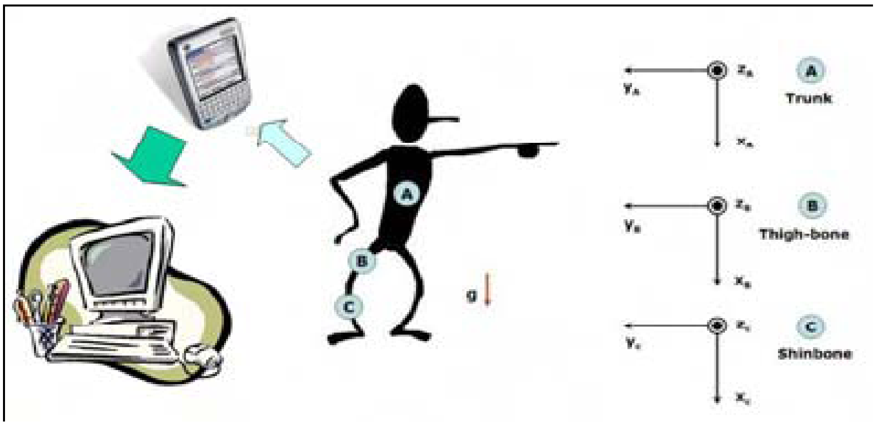


Figure 4: System structure

3. Posture Recognition Application

The user is equipped with 3 sensing modules. The aim is to detect posture among seven different possibilities which are, standing, sitting in two different positions and laying in four different manners. [2]

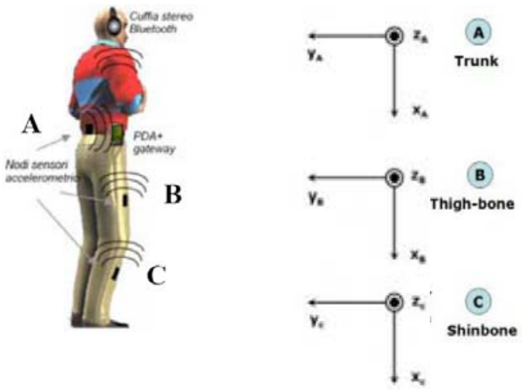


Figure 5: application

Sensors monitor the inclination of certain parts of the body, along three axes. Acceleration values are averaged then module-tilt with respect to the gravity axes is computed and encoded. Then this encoded data is sent to the gateway using scheduled MAC protocol. Data from three different nodes is combined at the gateway node to interpret body posture. Gateway node communicates with host machine where a Graphical User Interface (GUI) is updated to display current user posture.

3.1 Node Operation:

Three Conditions of axis are detected at three nodes: *Directed as*, *Orthogonal to* or *Opposed to* the gravitational acceleration. Thus three sub-ranges are identified. The set of three accelerations is associated to a specific 4-bit configuration identifying the tilt of the module [2]

X	Y	Z	Module Tilt (4 bit)
p	o	o	0000
o	o	g	0001
o	p	o	0010
o	g	o	0100
o	o	p	1000
g	o	o	1010
none	none	none	0101

Table 1: four bit code of module tilt according to sensor data

Where p =parallel but opposed to *g*,
g = directed as *g*,
o= orthogonal to *g* [2]

3.2 Gateway Opertion

Gateway microcontroller implements communication protocol with end-nodes and with the general purpose system. And then acquires and accumulates tilt data from each end-module for a given frame. Then it combines all module tilts to identify a known body configuration. Then it sends the identified position to the GUI application. [2]

Trunk	Thigh-bone	Shinbone	User posture (ASCII))
0000	0000	0000	1 (Standing)
0000	0001	0000	2 (Sitting)
0000	0001	0001	3 (Sitting with leg up)
1000	1000	1000	4 (Prone)
0001	0001	0001	5 (Supine)
0010	0010	0010	6 (Laying on right side)
0100	0100	0100	7 (Laying on left side)

Table 2: Postures detected at Gateway node according to the sensor data

It can initiate any specified task depending on certain sequence of detected postures.

E.g. a certain sequence can indicate that the user fell down, thus an alarm can be generated to contact assistance. [1]

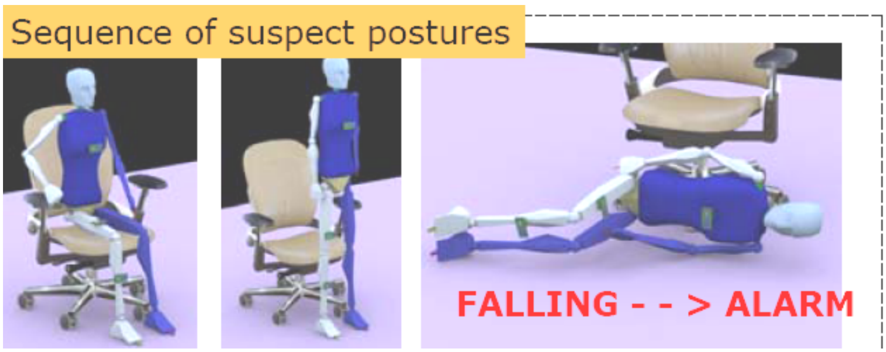


Figure 6: Sequence of detected postures to activate alarm

It handles setup of nodes and network tasks such s scheduling, synchronization etc.

4. WBASN Communication Layer

WiMoCA software implements a collision free MAC protocol. The CFRT (Collision Free Real-Time) protocol basically divides time into frames in which only one node is allowed to transmit. The scheduling order is derived by a Message Table stored in each node and identical for all the nodes, so that each of them knows when it has the right to transmit data. The timeline of the MAC protocol is as follows. [2]

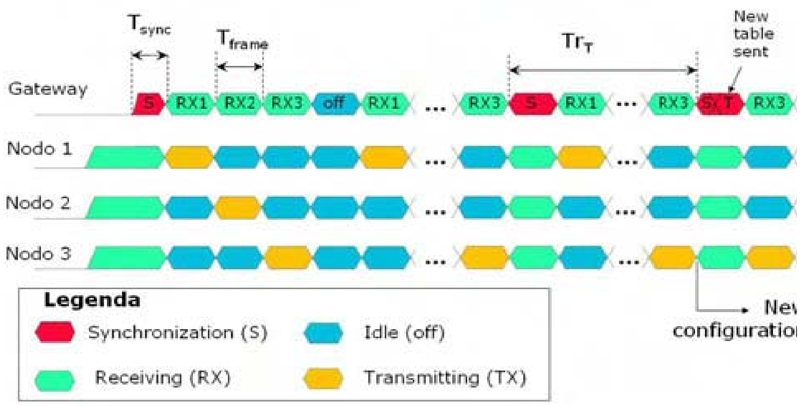


Figure 7: Time-line of MAC

The signal transmitted by the node:

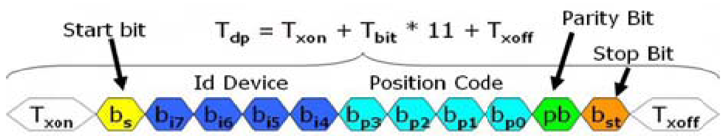


Figure 8: the signal transmitted by the node

5. Synchronization

Gateway node is taken as the reference node. After every *S* frames a *Synchronization Phase* takes place During this phase, nodes listen for the gateway that sends a synchronization packet that is used to synchronize the internal timer.
Condition on number of frames: $S \leq (Tbit/2)/DELTA$ [2]

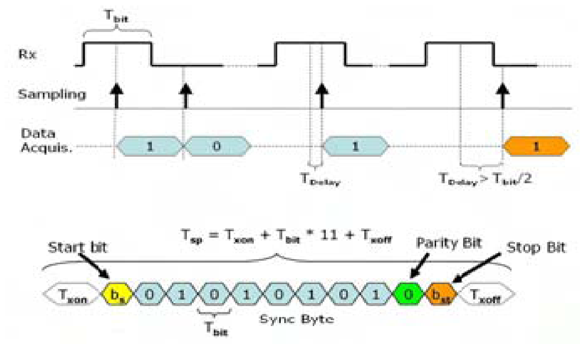


Figure 9: Synchronization phase:

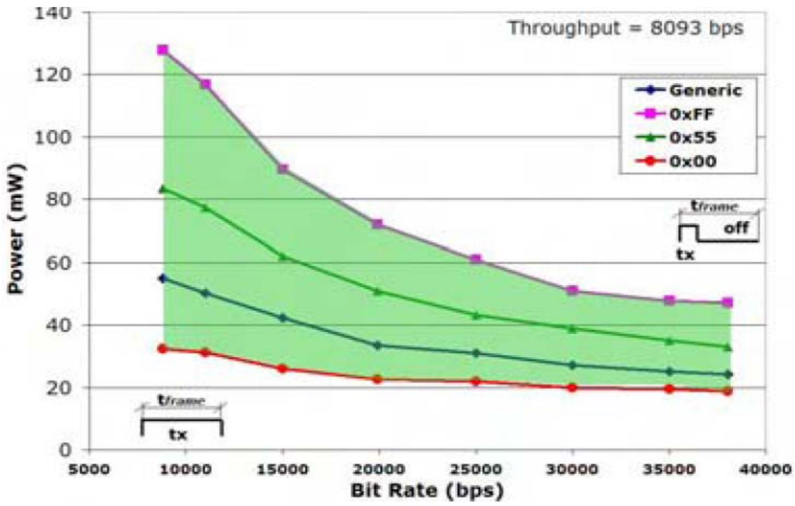
Where delta is interrupt execution response time. In current implementation where *T bit =31.25u-sec, and delta is 100 n-sec (for 4 MHz clock), a suitable value for S is 156 frames.*

6. Characteristics:

Parameter	Expression	Our case
Bitrate (br)	---	32Kbps
Number of nodes	N (max = 14)	3
Number of rows in a table	S	3
Number of node positions	P (max = 16)	5 (4 + don't care)
Bits in a synchronization packet	----	11
Bits in a data packet	----	11
Bits in a table-update packet	11 + 9*S	38
Transceiver On to Off time	T_{XOFF}	20 usec (TR1001)
Transceiver Off to On time	T_{XON}	20 usec (TR1001)
Transmission power needed to send "1"	P_{TX1}	151,8 mW
Transmission power to send "0"	P_{TX0}	21,38 mW
Rx power	P_{RX}	23,70 mW
Power in OFF state	P_{OFF}	15,27 mW
Transceiver ON to OFF Power = Transceiver OFF to ON Power	$P_{XON}=P_{XOFF}=P_{RX}$	23,70 mW
Latency	T_L	1,536 msec
Battery Energy	E_B	100 mAh

Table 3: Charcteristics of implimented system [2]

The average power consumption per frame as a function of bit rate is described in the graph. The system was operated at 32 kHz to minimize power losses. [2]



Graph 1: Power vs. Bit Rate

Total power consumption at maximum posture sampling is 46 mW in the worst case (transmission of all ones) and 16.85 mW in the best case (all zeros). With 3 nodes a maximum sample rate of 651 position per second (latency = 1,536msec) is achievable. In practical cases, the maximum frequency of human movement is 30Hz, so that 60 positions per second (latency = 16,7msec) is a sufficient rate for detecting postures without loosing information.

7. Conclusions:

This paper describes the design and implementation of WiMoCA, a wireless sensor node based on tri-axial integrated accelerometers, aimed at detecting human gesture and postures to implement a HCI (human computer interface) system. The concept of wireless body area sensor network is implemented exploiting WiMoCA nodes. The sensor network enables the implementation of a distributed recognition system to detect combined body postures and movements. All the software layers needed to support the acquisition, to implement the coordination and synchronization among nodes, to transfer gesture data up to the user application are also discussed. More research work is needed on developing codes to reduce the number of 1s in the data, to reduce transmission power. [2]

References:

[1] Elisabetta Farella, Augusto Pieracci, Davide Brunelli, Andrea Acquaviva,Luca Benini, Bruno Ricco´, “Design and Implementation of WiMoCA Node for a Body Area Wireless Sensor Network”, *Proceedings of the 2005 Systems Communications (ICW’05)*, University of Bologna Italy, ISTI - Urbino University, Italy 2005.

[2] Elisabetta Farella, Augusto Pieracci, Luca Benini, Andrea Acquaviva, “A Wireless Body Area Sensor Network for Posture Detection”, *Proceedings of the 11th IEEE Symposium on Computers and Communications (ISCC'06)*, DEIS - University of Bologna Italy, ISTI - Urbino University Italy 200