AN OVERVIEW OF SENSOR NODES FOR WIRELESS SENSOR NETWORK APPLICATIONS: A REVIEW

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Abstract: It is found that, the industrial sector is demanding sophisticated electronics system, wherein the industrial parameters should be centrally monitored. The industrial parameters such as environmental humidity, temperature, leakages of hazardous gasses from process plants etc are widely distributed and depict spatio-temporal variations. The industrial environmental pollution monitoring has global significance. Therefore, emphasizing present needs of the industries, it is essential to develop the Wireless Sensor Network (WSN), wherein typical industrial parameters are precisely monitored at central station. In fact, the WSN consists of autonomous sensor nodes, battery powered, connected to the base station using wireless networking topology. Deploying a ubiquitous embedded technology the sensor nodes of required features can be designed. Recently, ARM technology is resulting into the microcontrollers of promising features, deploying which the wireless sensor node can be designed. The WSN is used to monitor typical parameters of the dedicated industries and design issues od the sensor nodes are presented in this paper. Present research work encompasses the field such as WSN, sensor node, Zigbee, IEEE 802.15.4, embedded design etc. Therefore, these fields have been extensively studied and presented in this paper.

Keywords: Sensor nodes, Wireless Sensor Networks, Microcontroller, Zigbee etc.

1. Introduction:

Indeed, the Wireless Sensor Network (WSN), the realization of distributed architecture, is an innovative field to ensure Site Specific Data Management (SSDM). Industrial sector reveals the spacio- temporal variance in case of various physical as well as chemical parameters. In case of industry the parameters such as, the process parameters and environmental parameters are of great interests. The physical parameters such as temperature, relative humidity, concentration of typical gases in the air etc and chemical parameters such as pH of the solution, salinity of the water etc must be monitored and controlled to the desired level to increase the productivity without compromise in the quality. In case of typical industry both indoor as well as outdoor environment must be monitored and controlled. For collection of the data of industrial parameters of Site Specific variability, the Wireless sensor network is most suitable.

On extensive study of the literature and survey of the industries, such as Sugar industry, Alcohol industry, Textile industry, milk processing, food processing industry, paper and pulp making industries etc, it is found that, the sophisticated industries are demanding an electronic system of a great preciseness and reliability to monitor and control the various parameters. Typical industries such as power generation plants are availing DCS or SCADA systems of networking to collect the information of the parameters. However, these are wired networks. Such architecture depicts the complexity in the hardware and hence hard to debug the faults. Moreover, the power consumption and power loss is also significantly high. To overcome the problems of wired networking and to ensure sophistication in data collection and dissemination, the industries are demanding Wireless Sensor Network. Thus, on extensive survey of various industries, it is found that, the industrial sector is demanding sophisticated electronics system, wherein the industrial parameters are centrally monitored. It is also found that, at present some industries are using the wired network for measurement of parameters and controlling of the process. This wired network ensures the mesh of wires from place of data to the controlling base station and the physical connection are complex. Therefore, debugging and fault finding becomes troublesome. To avoid this problem many times the standby network is also suggested. This wired network not only increases the complexity but also exhibit tremendous loss of power for transmission of signal through the transmission lines. Secondly, transmission signal through wire is the one of the causes to introduce the noise, which reduces the signal to noise ratio. To avoid these problems of industrial sector, the wireless communication is most suitable technology. A wireless sensor network is suitable to replace the present wired network.

In fact, the WSN consists of autonomous sensor nodes, battery powered, connected to the base station using wireless networking topology. To ensure reliability in WSN, the sensor node must be highly reliable and precise. Moreover, it should low power and low cost device. Presently an embedded technology is becoming more ubiquitous and can be deployed to design sensor nodes of required features. Recently, ARM technology is resulting into the microcontrollers of promising features, deploying which the wireless sensor node can be designed. Moreover, the 32-bit philosophy of ARM processor helps to enhance the preciseness in the monitoring of the parameter values. The Zigbee technology is pervasively advancing. It can be used to ensure wireless communication. Therefore, to overcome present day problem of industrial sector and to ensure wireless data transfer with high accuracy and reliability, it is essential to design Wireless Sensor Network and implement the same for industrial environmental monitoring.

2. Review of Literature

Indeed, the Wireless Sensor Network (WSN) is an emerging field of electronics, ensuring research of applied nature. The salient features of wireless sensor network motivate to undertake the research work in this field. According to the architecture, the wireless sensor network (WSN) consists of a thousands of self-organizing, lightweight sensor nodes, which are used to monitor physical or environmental conditions. Normally, the parameters considered for monitoring include temperature, sound, humidity, vibration, pressure, gases, motion etc [1]. Each sensor node in a

WSN is equipped with a RF module, an array of sensors, a battery unit and a Central Processing Unit (CPU). Although, research in the field of WSN was initially motivated by military applications. Now days, it is deserving a key position in many industrial and public service areas including traffic monitoring, weather conditions monitoring, video surveillance, industrial automation and healthcare applications [2]. The node communicates wirelessly and self organize after being deployed in an ad hoc network. The WSN realizes the deployment of IEEE 802.15.4 standard for wireless communication. The Zigbee technology is playing vital role in establishment of WSN for dedicated applications. Currently, wireless sensor networks are widely deployed in diverse areas. It is expected that, within few years the world may be connected with wireless sensor network and provides accession with the internet, to realize the concept of Internet of Things (IOT) [3-5]. In establishment of WSN, the nodes are autonomously operating at remote places. Therefore, the minimizing the power consumption is one of the key issues [6]. Therefore, precise and low power nodes are required for development of wireless sensor network. In facts, the nodes can be designed with microcontrollers of prominent features. The features of the nodes vary with the designing issues of hardware and firmware. Therefore, designing of nodes of prominent features is one of the challenging jobs. Therefore, many researchers are exhibiting significant interest in developing wireless sensor node and wireless sensor network for dedicated applications.

3.An Architecture of Wireless Sensor Network (WSN)

Wireless sensor network (WSN) is the distributed network of large number of wirelessly connected autonomous devices, called Wireless Sensor Nodes, which collaboratively collects the information about physical world and disseminates the same towards the monitoring stations called Base Station (BS) for the deterministic analysis and presentation [7-9]. The general architecture of wireless sensor network is shown in figure 1. The WSN is an infrastructure comprised of sensing, computing and communication elements, which provides the information about area and process of interest to the administrator, to ensure the sustainable management [10]. As depicted in figure 1, the WSN comprises following four components.

1. An assembly of distributed Wireless Sensor Nodes.
2. An interconnecting wireless network in suitable protocol.

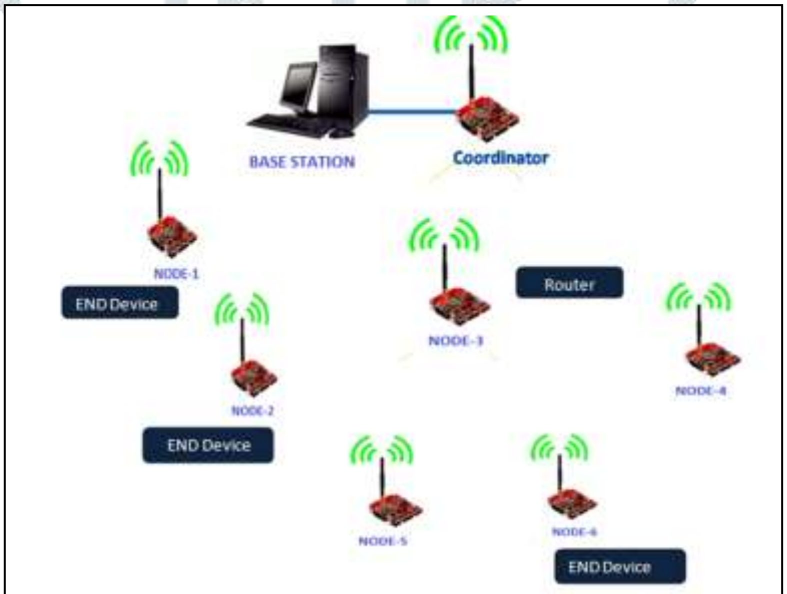

Figure 1: Architecture of Wireless Sensor Network

3. A smart base station.
4. A set of computing devices required for data computation, co-relation, event, trending, status querying and actuations etc.

4. The Wireless Sensor Node (SN)

To establish wireless sensor network, the features of wireless sensor nodes (SNs) play commendable role on the enhancement of accuracy and reliability of WSN [11]. Therefore, the sensor node must be highly accurate and reliable. To enhance characteristics of sensor node the embedded technology is most suitable. Wireless Sensor Node is smart device and operating as the End Devices (ED) to interact with the physical world, as the Router to collect the data from the sensor nodes and disseminate towards the Co-ordinator node. The wireless sensor nodes are mostly distributed in wide geographical area. Each sensor node has the capabilities to collect the data and disseminates to the coordinator. The data is routed to the coordinator by multihop infrastructure. The general architecture of the Wireless Sensor Node is depicted in figure 2

a) General Architecture of Wireless Sensor Node (SN):

The general architecture of the Wireless Sensor Node (SN) is presented as the block diagram shown in figure 2. A Wireless Sensor Node, can be named as a mote [12], is a unit cell of a Wireless Sensor Network (WSN), which is capable of sensing, processing, gathering information and communicating with other nodes of the network and/or base station as well. Present work emphasizes the development of wireless sensor network for industrial applications, for which the node of promising features are required. The details regarding designing of the sensor nodes are given in next topics. However, the general consideration about sensor node is discussed in this article.

The general architecture of SN is presented in figure 2. The main components of sensor nodes (SN) are a microcontroller, transceiver, power source and array of the sensors [figure 2]

1. **Computing Unit (The Microcontroller):** The computing unit performs tasks of processing the data and controlling the functionality of other components of the sensor node (SN). Normally, the computing unit of node is wired about a microcontroller of prominent

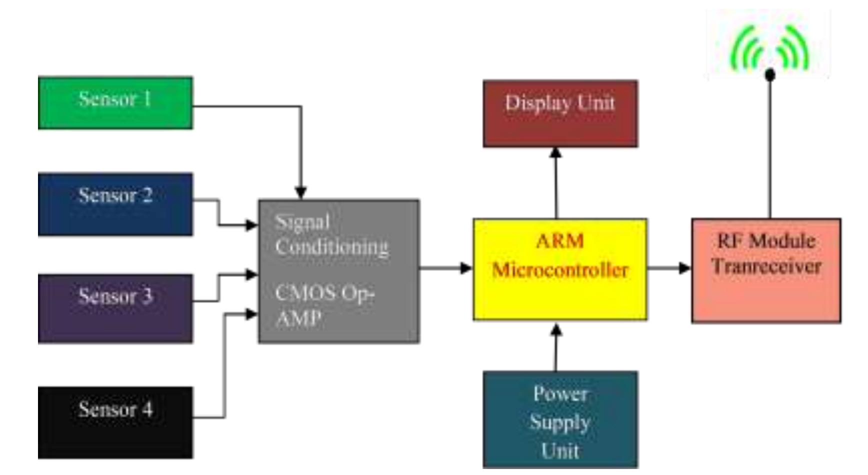

Figure 2: Block Diagram of Wireless Sensor Node (SN)

features. However, the general purpose microprocessor, digital signal processors, FPGAs and ASIC etc play significant role. Now days, the mixed signal based SoCs are evolving, which play commendable, job of computing for sensor nodes. A microcontroller is often used in many embedded systems because of its low cost, flexibility to interface ease of programming and low power consumption. A general purpose microprocessor generally has higher power consumption than a microcontroller. For present WSN, the sensor nodes are wired about ARM microcontroller from LM4F120H5QR family.
2. **Communication Device:** Communication device is used to establish interaction between individual SNs and with the base station as well. The communication medium between the two SNs is through radio frequencies. Radio frequency-based communication fits the requirements of most of the wireless sensor applications because it provides relatively long range and high data rates at reasonable energy expenditure. Also, it does not require line of sight between sender and receiver. The 915 MHz and 2.4 GHz Industrial, Scientific and Medical (ISM) bands have been widely suggested for WSN [13]. For actual communication, both a transmitter and a receiver are required in a SN. The essential task is to convert a bit stream coming from a microcontroller and convert them to and from radio waves as half duplex operation is recommended in Wireless Sensor Network. In the transceiver, circuitry includes modulation, demodulation, amplifiers, filters, mixers. The details regarding use of frequency band and types of modulation adopted are presented in next article. In fact, it is mandatory to follow the IEEE 802.15.4 standards. The transceiver must provide an interface that allows the medium access control (MAC) layer to initiate frame transmissions and to hand over the packet from the main memory of the sensor node into the transceiver. In other direction, incoming packets must be streamed into buffers accessible by MAC protocol.
3. **Memory:** To ensure deployment of embedded technology the most relevant memory is the on-chip memory of the microcontroller. The Off-chip RAM is rarely used. Flash memories are used due to their cost and storage capacity. On-chip memory is sufficient for supporting entire operation of SN.
4. **Power source:** Deployment of stored energy or harvested energy from the outside world, are the two options for the power module. Energy storage may be achieved with the use of batteries or alternative devices such as fuel cells or miniaturized heat engines, whereas energy-scavenging opportunities [14] are provided by solar power, vibrations, acoustic noise, and piezoelectric effects [15]. The majority of the existing commercial and research platforms relies on batteries, which dominate the node size. Primary rechargeable batteries are often chosen, predominantly AA, AAA and coin-type. Voltage regulation could in principle be employed, but its high inefficiency and large quiescent current consumption call for the use of components that can deal with large variations in the supply voltage [16]. Rechargeable batteries are normally recommended.
5. **Sensors Array:** To ensure site specific data management (SSDM), the facets of WSN, the SNs dedicatedly operate to collect physical information, for which an array of sensors is required. The sensor array should consist of sensors as per required parameters. A salient feature of the sensor decides the reliability of the SN. Additional issues are the physical size of the sensing hardware, fabrication, and assembly compatibility with other components of the system. Packaging requirements are also significantly important for sensors such as chemical sensors which require contact with the environment [17]. Using a microcontroller with an on chip analog comparator is another energy-saving technique which allows the node to avoid sampling values falling outside a certain range [18]. The ADC which complements analog signal is particularly critical, as its resolution has a direct impact on preciseness in the data. Micromachining techniques have allowed the miniaturization of many types of sensors without compromise with the performance. Standard integrated circuits may also be used as temperature sensors or light intensity transducers (e.g. using photodiodes or phototransistors) [19]. Nanosensors can offer promising solutions for physical and chemical parameters. Thus, the sensor and transducer interface unit of the

SN plays vital role on the performance of the SN.Emphasizing this basic architecture, sensor nodes (SN) have been developed and details regarding designing issues are interpreted in next section.

4.1Types of Nodes

Objectives of the present research work are to design Sensor Nodes (SN) of desired features and deployment of same to establish WSN for typical industrial applications. However, the Sensor Nodes (SN) launched by different vendors is intensively studied. From this investigation it can be said that, different types of SN of their own salient features are available. Some of them are having low power consumption with limited computing capability, whereas many sensor nodes are showing good communication capabilities. As a representative, some SN isdiscussed in this topic. A comparative study of features of these nodes are tabulated and presented in table 1.

TABLE 1: Comparative representation of features of the various SN.

Parameters	MicaZ	TeleosB	IRIS	SHIMMER	LOTUS	T-Node	SUNSPOT	Cricket
Manufacturer	Crossbow	UC Berkeley	Crossbow	Intel	MEMSIC	SNOWNet technologies BV	Sun	MEMSIC
Features	Expansion connectors for attaching external sensors	Low power microcontroller and RF module	3-times radio compared to MICA nodes at half the power consumption	Supports Bluetooth, Real time capability, for long term wearable use	Low power cortex-3 CPU	868MHz radio together with ultra low power multi-hop networks	Open source hardware and Software	Third generation low power node
Controller	ATMega 128L	TI MSP430F1611	ATMega128 L	TI MSP430F 1611	NXP LPC-1758	ATMega128L	AT Mega91 RM9200	ATMega128 L
BUS Size	8	16	8	16	32	16	32	16
Frequency(Hz)	16	8	16	8	10-100Hz	32	180	8
Wake-up Time(μs)	180	6	4300	6	-	-	Pin change	-
FLASH(Bytes)	128k	48K	640k	48k	512k	512k	4M	128k
RAM(Bytes)	4k	10K	8k	10k	64k	4k	512k	4k
EEPROM(Bytes)	512k	1M	4k	No support	64M	4k	No support	4k
Serial Communication	UART	UART	UART	UART	UART/SPI/I2C	UART	UART	UART
OS Support	MantisOS	Contiki, Mantis OS	Mote Runner MoteWorks	TOS	-	-	Squawk-VM(Java)	-
Radio Chip	CC1000	CC2420	AT RF230	CC2420	RF-131	CC1000	CC2420	-
Data Rate(kbps)	38.4/250	250	250	250	250	250	250	250
ISM Band	300-1000/2400-2483.5	2400-2483.5	2400-2483.5	2400-2483.5	2400-2483.5	868/2400-2483.5	2400-2483.5	2400-2483.5
Current Receiving(mA)	18.8	19.7	16	18.8	16	12	18.8	-
Current Transmitting(mA)	17.4	17.4	17.4	17.4	10	18	17.4	-
Power Consumption Receving(mW)	56.4	56.4	48	56.4	3	-	56.4	-
Power Consumption Transmitting(mW)	52.2	52.2	51	52.2	3	-	52.2	-
Modulation Technique	O-QPSK	O-QPSK	O-QPSK	O-QPSK	O-QPSK	O-QPSK	O-QPSK	O-QPSK

Figure 3: MicaZ Sensor Node Designed by Crossbow Technology

Figure 4: TelosB Sensor Node

MicaZ: The MicaZ is a 2.4 GHz sensor node used for enabling low power, wireless sensor networks. It is good example of an embedded system. The MicaZ specifically uses the Atmel ATmega128L microcontroller. The ATmega128L is a low power microcontroller. The MicaZ sensor node has I2C, SPI and UART interface. According to IEEE 802.15.4, radio offers both high speed and hardware security such AES-128 encryption. The figure 3 depicts the MicaZ sensor node. The Mica2/Micaz is the second and third generation mote technologies from CrossBow Technology [20].

a) **TelosB:** TelosB is an ultra-low power wireless sensor node.It uses the features of chipcon wireless transceiver such as 250kbps,

Figure 5: IRIS Sensor Node

Figure 6: SHIMMER Sensor Node

Figure 7: LOTUS Sensor Node

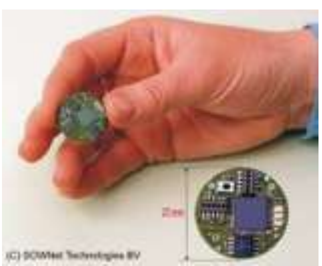

Figure 8: T-Node Sensor Node

Figure 9: SUN SPOT

Figure 10: Cricket Sensor Node

2.4GHz. The figure 4 depicts the photograph of TelosB sensor node. The Microcontroller from Mixed signal family MSP430 is employed in designing which runs on 8MHz. TelosB have 16- pin expansion support and optional SMA antenna connector. It was first designed by the US Berkeley and now available from Sentila and Crossbow Technology [21].

b) **IRIS:**The IRIS is a 2.4 GHZ mote used to establish low power, wireless networks. The IRIS sensor node features hundreds of new capability that enhance the overall functionality of Crossbows wireless sensor networking products. The IRIS is three times better than MicaZ sensor nodes [22]. The figure 5 depicts the photograph of the IRIS sensor mote.

c) **SHIMMER:** The SHIMMER stands for Sensing Health with Intelligence, Modularity, Mobility and Experimental Reusability. The SHIMMER is small platform that can record and disseminates the physiological data in real time. The SHIMMER sensor node has on-chip sensors such as ECG, EMG, GSR, Accelerometer, Gyro, GPS, Tilt and Vibration sensors [23]. The figure 6 depicts the photograph of a SHIMMER sensor node.

d) **LOTUS:** The Lotus is an advanced wireless sensor node platform. It is built around the low power Cortex M3 CPU and also integrates on 802.15.4 compliant radio. The figure 7 depicts the photograph of Lotus sensor node. On Lotus node the LPC17XX 32-bit ARM Cortex-M3 based microcontroller is employed for embedded applications. The Lotus uses the RF231 IEEE 802.15.4 radio transceiver from Atmel.

e) **T-Node:** The T-node allows OEM partners to build their own wireless solution for the market using the 868MHz radio together with ultra low power multi-hop networks protocols like mesh, star and single hop topologies. T-node uses an 868 MHz radio to achieve upto

120m communication distance outdoors line of sight free space, while consuming as little as 20µA in sleep mode. The T-node support 10-bit ADC, interrupt, digital I/O, I2C and UART interface. The figure 8 depicts the photograph of T-node.

f) SUN SPOT: The Sun Spot means Sun Small Programmable Object Technology and developed by Sun Microsystems [24]. The device is built on IEEE 802.15.4 standards. The figure 9 depicts the photograph of SUN SPOT sensor node.

g) Cricket: The Cricket sensor node is location aware version of the popular Mica2 low power processor radio module. The Cricket is a third generation mote used for enabling low power wireless sensor networks.

h) **EZ430-RF2480/F2500T**: These are wireless networking solutions from Texas Instruments [25-26].

i) Waspmotes: Wasp motes are open source hardware and software sensor platform from Libelium Communications [27].

Therefore, on extensive study of the different sensor nodes, it is found that, the sensor nodes currently available in the market is mostly based on 8-bit platforms and there is need to upgrade these sensor nodes. Therefore, in present research work, the sensor node is designed with help of advanced microcontroller from Cortex-M4 Stellaris family based LM4F120H5QR 32-bit ARM microcontroller. Moreover, the SN designed for present purpose employs Xbee for RF communication. Therefore, range of communication is significantly increased. Moreover, many features are significantly improved and cost is substantially reduced. Hence, present SN can suitably deploy for industrial applications.

References:

[1] M. Loy, R. Karingatti and L. Wiliems, "Application Report: ISM-Based and Short Range Device Regulatory Compliance Overview", 1-16.

[2] I. Akyildiz, W. Su, Y. Sankarasubramaniam and E. Cayirci, "A survey on sensor networks", Communications Magazine, IEEE, 40 8(2002) 102-114.

[3] S. Shieh, "IOT Security: Ongoing Challenges and Research Opportunities", IEEE Int. Workshop on Internet of Things Services, 17-18 Nov (2014), Matsve, Japan.

[4] K. Ashton, "That 'Internet of Things' Thing ", RFID Journal, 2009

[5] L. Li, H. Xiaoguang, C. Ke and H. Ketai "the Application of Wi-Fi Based Wireless Sensor Network in Internet of Things and Smart Grid", Industrial Electronics and Applications (ICIEA), 6th IEEE cone. On 21-23 (June 2011), Beijing, 789-793.

[6] K. Shnghal, A. Noor and N. Srivastva, "Power Measurement of Wireless Sensor Network Node", IJCES, (2011), ISSN 2231-6590.

[7] H. Wu, Y. Wang, H. Dang and F. Lin, "Analytic, Simulation and Empirical Evaluation of Delay/ Fault Tolerent Mobile Sensor Network", IEEE Trans. on Wireless Communication, 69 (2007) 3287-3296.

[8] A. Hamzi, M. Koudil, J. Jamont and M. Occell, "Multi-Agent Architecture for the Design of WSN Applications", Wireless Sensor Network, 5 (2013) 14-25.

[9] E. Yoneki and J. Bacon, "A Survey of Wireless Sensor Network Topologies: Research Trends and Middle Ware's Role", Technical Report, UCAM-CL-TR-646 University of Cambridge, Cambridge (2005).

[10] K. Sohraby, D. Minoli and T. Znati, "Wireless Sensor Network: Technology, Protocol and Applications", John Willey and Son. Inc, (2007).

[11] M. Katiyar, H. Sinha and D. Gupta, "On Reliability Modeling in Wireless Sensor Networks: A Review", Int. J. of Comp. Sci., 9 6 (2012) 99-105.

[12] http://en.wikipedia.org/wiki/Sensor_node

[13] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "A Survey on Sensor Networks," IEEE Communications Magazine, 40 8 (2002) 102–114.

[14] S. Roundy, P.Wright and J. Rabaey, "A Study Of Low Level Vibrations As A Power Source For Wireless Sensor Nodes", Computer Communications, 26(2003) 1131–1144.

[15] J. Kymissis, C. Kendall, J. Paradiso, and N. Gershenfeld, "Parasitic Power Harvesting In Shoes",Proceedings of the 2nd IEEE International Symposium on Wearable Computers, Pittsburgh, PA, (1998).

[16] L. Ni, "Wireless Sensor Networks", Proceeding of IEEE International Conference on Sensor Networks, Ubiquitous, and Trustworthy Computing, 19 (2008).

[17] B. Arneke and K. Pister, "MEMS for Distributed Wireless Sensor Networks", Proceedings of the 9th International Conference on Electronics, Circuits and Systems,1 (2002)291–294.

[18] Z. Karakehayov, "Low-Power Design for Smart Dust Networks", Handbook of Sensor Networks: Compact Wireless and Wired Sensing Systems, (2004), 37.1–37.12.

[19] B. Warneke, "Miniaturizing Sensor Networks with MEMS", Handbook of Sensor Networks: Compact Wireless and Wired Sensing Systems, (2004), 5.1–5.19.

[20] S. Gajjar, S. Pradhan, K. Dasgupta, "Wireless Sensor Networks: Application led research perspective", Proc. of IEEE Recent Advances in Intelligent Computational Systems, (2011) 25 – 30.

[21] K. Pister, "Centre for embedded network sensing", http://research.cens.ucla.edu/.

[22] Moog Crossbow Technologies Wireless Sensor Network products [Online]. Available: http://www.xbow.com/.

[23] MEMSIC International corporation Wireless Sensor Network products [Online] Available: http://www.memsic.com/.

[24] Realtime Technologies Wireless Sensor Network products [Online] Available: http://www.realtime.ie/.

[25] User guide eZ430-RF2480 [Online] Available: http://www.ti.com/lit/ug/swru151a /swru151a.

[26] User guide eZ430-RF2500 [Online] Available: http://www.ti.com/tool/ez430-rf2500.

[27] Libelium Communications waspmote catalogue [Online] Available: http://www.libelium.com/products/ waspmote/.