International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249 – 8958, Volume-5, Issue-3, February 2016

Smart Antenna System for Wireless Sensor Networks to Improve Energy Efficiency

Mohamed Hanaoui, Rachid Aouami, Mounir Rifi

Abstract—This paper presents the design and implementation of smart antenna system in wireless sensor network severely to minimize the energy consumption due a interference constraints. The integration of in wireless sensor networks is a challenging and very attractive technical solution to improve the system capacity, the quality of service, and the power control. Smart antenna system has the advantage over traditional omnidirectional antennas system), of being able to orientate signals into the desired direction in either transmission node or reception node. In this paper, we create a view of ground with nodes by using MATLAB, then we compare active communication using SAS and active communication using OAS using the static topology. The designed system provides a flexible and low cost solution for us to make in the smart-home and office smarter. The energy efficiency to bring by smart antenna system is described.

Index Terms—smart antenna, omnidirectional antenna, wireless sensor network, nodes, energy efficiency.

I. INTRODUCTION

A wireless sensor networks consists of a large number of small sensor nodes with sensing, data processing, and communication capabilities able to realize a distributed and remote monitoring/control of the environment. In several applications, the network nodes are randomly deployed, therefore the whole wireless architecture should be characterized by a highly dynamic and reconfigurable topology with self-organizing capabilities to guarantee an energy efficient transmission of the information on the scenario under test. Such a behavior is mainly concerned with the strategy of medium access protocol (MAC) at the network layer as well as with the smart management of the physical layer to extend the node/network lifetime and to exploit the space selectivity. In this context, the adoption of a smart antenna system [1-2] at the communication interface is certainly an optimal solution not only to reduce the RF-energy consumption, but also in order to maximize the efficiency of the data exchange among the network nodes. Over the last few years, a strong research effort has been dedicated to the design of more and more performing Smart Antenna System [3-8]. Nevertheless, their integration in WSN nodes to minimizing the energy consumption and to extend nodes lifetime, has not been exhaustively explored yet. In particular, a switched-beam antenna for WSNs nodes in the ISM band (2.4-2.4835 GHz) is proposed in [3].

Revised Version Manuscript Received on February 26, 2016.

Mohamed Hanaoui, Ph.D Student of Computer Sciences at Laboratory RITM (Networks, Computer, Telecom and Multimedia), CED Engineering Sciences in ENSEM School Casablanca.

Rachid Aouami, Ph.D Student of Computer Sciences at Laboratory RITM (Networks, Computer, Telecom and Multimedia), CED Engineering Sciences in ENSEM School Casablanca.

Mounir Rifi, Director of EST (Ecole Superieure de Technologie) at the University Hassan II of Casablanca.

It is consists of four identical antennas, composed of an array of two L-shaped quarter-wavelength slot antenna elements arranged in a compact and symmetrical planar structure, thanks to a properly designed switching circuit which controls the feeding of the antenna elements, one among eight possible different radiation patterns in the azimuth plane can be selected on the basis of specific needs. A smart switched-beam directional antenna is proposed in [5]. It is composed of four planar patch antennas arranged in a box-like structure. It can switch among four radiation beams with a uniform coverage of the azimuth plane and a good radiation gain in the main lobe direction. A reconfigurable angular diversity antenna using quad corners as reflector arrays and a switching control circuit is proposed in [6]. It presents a high radiation gain. A compact Switched-Beam Antenna composed of a four-element antenna array is presented in [7]. It shows eight switchable directional patterns and an omnidirectional one, thus ensuring an uniform coverage of the 360 degrees horizon. Moreover, it is both compact and inexpensive. Unfortunately, it exhibits a Half-Power Beam Width (HPBW) of a single beam of nearly 120 degrees.

In this work, we study an uniform linear antenna array prototype of smart antenna system. We demonstrate the appropriateness of the smart antenna system than omnidirectional antenna, as hardware element enabling new power saving strategies in WSN contexts.

The paper is structured as follows: in Sections II and III, the state of the art on wireless sensor networks and smart antenna system are discussed, whilst in section IV, a comparative study between nodes with smart antenna and nodes with omnidirectional antenna are described, next in section V simulation results are shown and discussed, in section VI we study the energy efficiency brought by a smart antenna. Finally, conclusions are drawn in final section.

A. Wireless Sensor Networks

Wireless sensor technology actually driven by powerful factors such as innovative wireless communications, low cost and power efficient, small sensing devices availability, coupling to Internet services, green application fields. The source station emits data fragments one after the next, and when the receiver misses a fragment, informing the sender can be retransmits his fragment. In the near future, multitude wireless communication network based on a variety of radio access technologies and standards will emerge and coexist. The availability of multiple access offers the capability of increasing the overall transmission capacity, providing better service quality, dealing with health problems of wireless systems and reducing the deployment costs for wireless access. In this way, all existing technologies [4.8] will become simple RATs (ZigBee, MTM, HSPA, WLANs, WiMAX,

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.

LTE, etc.) The capacity of wireless sensor networks can be severely limited due to interference constraints. One way of using improving the overall capacity of sensor networks is by the use of smart antennas. Smart antennas allow the energy to be transmitted or received in a particular direction as opposed to disseminating energy in all directions. This helps in achieving significant spatial re-use and thereby increasing the capacity of the network. Typically, these antennas are deployed at base-stations in these networks to sectored cells and focus transmissions in certain directions. A WSN consists of a collection of wireless mobile stations (nodes) forming a dynamic network whose topology changes continuously and randomly, and its intermodal connectivity's are managed without the aid of any centralized administration. In contrast, a centralized administration or base station controller (BSC) manages cellular networks where each node is connected to a fixed base station. Moreover, cellular networks provide single hop connectivity between a node and a fixed base station while WSNs provide multihop connectivity between Nodes A (source) and Node B (destination), as illustrated in Fig 1. This figure shows an example of two nodes, Node A and Node B, that desire to exchange data, it is necessary for Node A to use the neighboring or intermediate nodes in forwarding its data packets to Node B. In other words, the data packets from Node A are passed onto the neighboring nodes in a series of single hops until the data packets reach Node B. This type of interaction among nodes is referred to as peer to peer and follows a set of rules for communication.

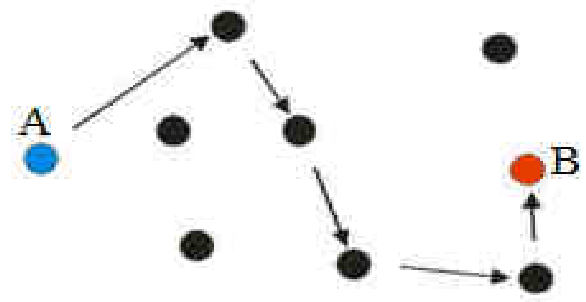


Fig. 1. Multihop example of wireless sensor networks

B. Smart Antenna System

Smart Antenna system is the One of the most rapidly developing areas of communications. This is the survey of our paper which shows principle and working of smart antennas and the elegance of their applications in various fields such as WSN. The term smart antenna generally refers to any antenna array, terminated in a sophisticated signal processor, which can adjust or adapt its own beam pattern in order to emphasize signals of interest and to minimize interfering signals [9-10]. Smart antennas generally encompass both switched beam and beam formed adaptive systems. Smart antennas have numerous important benefits in wireless applications as well as in sensors such as radar. In the realm of mobile wireless applications, smart antennas can provide higher system capacities by directing narrow beams toward the users of interest, while nulling other users not of interest, by using several techniques of forming the radiation beam toward desired node [1]. The geometry of each antenna array is arbitrary, i.e., each antenna element can be put in any position and orientation. However, once the geometry of the array has been chosen it is assumed fixed for the whole duration of the simulation. In other words, while the array can be moved at will in the free space, the relative position of the antenna elements is fixed. A set of predefined antenna arrays is included. The predefined geometries are: Uniform Linear Arrays (ULA), Uniform Circular Arrays (UCA), and Uniform Rectangular Arrays (URA) [2]. The number of antennas can be set at will.

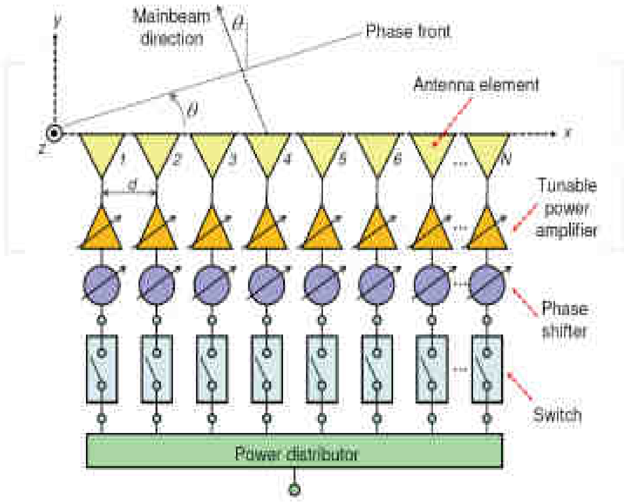


Fig. 2. Configuration of a linear array antenna.

We consider a linear array of N equispaced isotropic antenna elements positioned along the x-axis. These antennas are supplied with same current amplitude and with a gradient of phase φ_i.

For a point situated in the zone of far radiation, all the directions of observation are parallel. The field radiated by this array $E(M)$ and the array factor $AF(\theta)$ can be obtained by considering the elements to be point source, which is given by [12-13]:

$$E(M) = \underline{E_0} \sum_{i=0}^{n-1} e^{j(i\psi_i)} \quad (1)$$

With $\psi_i = \varphi_i + Kd_i \cos\theta$ (2)

$$AF(\theta) = n * \frac{|\sin(n\psi/2)|}{|\sin(\psi/2)|} \quad (3)$$

Where $\varphi_i \in [\varphi_0, \varphi_1 ...., \varphi_{N-1}]$ represents the phase excitation of the nth element (the antenna in the beginning is taken as reference of phase: φ_0), d_i represents the position of the nth element, $K = 2\pi/\lambda$ is the wave number, θ is the angle of incidence of desired signal or interfering signal, and λ is the signal wavelength.

II. Energy Efficiency

The sensor nodes are microelectronic devices, can be equipped only with a limited power source. The lifetime of a sensor is dependent on the life of its battery. This energy is consumed by the various sensor units to achieve the collection spots, data processing and communication, this latest is the operation that consumes the most energy.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.

A. Implementation of our system

The system architecture consists of a configuration block that creates an entire network having various sensor nodes and a desired node, which could be also called as a base station or the destination node to which the packets has to be diverted. The sensor nodes will have the knowledge, as from which node the packet is received and to which node it has to be diverted. These all procedures will be carried over in the Geo routing next hop engine. This engine will calculate the nearest available node for the transmission of the packet and will be sent by using beam forming technique. The desired node will be the destination part of the overall system, it just tunes to the desired location using the algorithm and receives the data packet such implementation is done by creating a Ground with nodes in MATLAB R2015a. The wireless sensor networks of 40 randomly nodes are created in the area of 500*500 meters and the connection is established between the nodes. Say for example, A to the base station (BTS). These are illustrated in the Fig. 3

B. Simulation Results

The objective of this study is decomposed into two parts: The first part is the creation of the infrastructure of sensor networks, the system must manage a connection of communication between a large numbers of nodes of networks. And the second part is the using the smart antennas of the communication between nodes in an effective way for a static topology. In this part, we present the simulation results of established connection between nodes. The parameters are reported in the following table.

TABLE I. DESCRIBES THE ITEMS THAT ARE KEPT FOR DIFFERENT SIMULATIONS.

Parameters	values
packet payload	8184 bits
MAC header	272 bits
PHY header	128 nits
ACK	112 bits +PHY header
Area	500*500m
Channel Bit Rate	1 Mbits/s
Slot Time	50µs
Propagation Delay	1µs
SIFS	28µs
DIFS	128µs
ACK_Timeout	300µs
CTS_Timeout	300µs

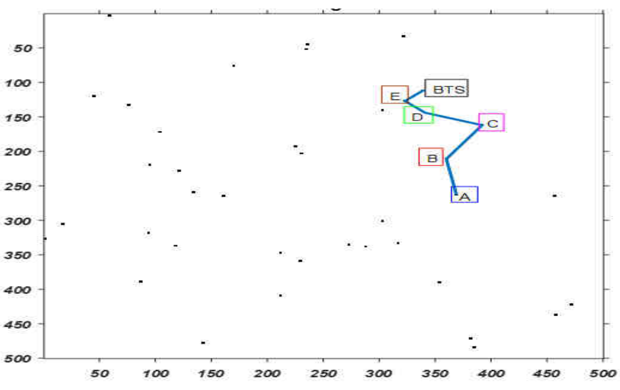


Fig. 3. Establishing a connection between nodes.

In the simulation results, firstly we shall concentrated on active communication between nodes using omnidirectional antenna system as seen in the Fig. 5. Secondly we concentrated on active communication between nodes using smart antenna system with bi activate beam as seen in Fig. 6.

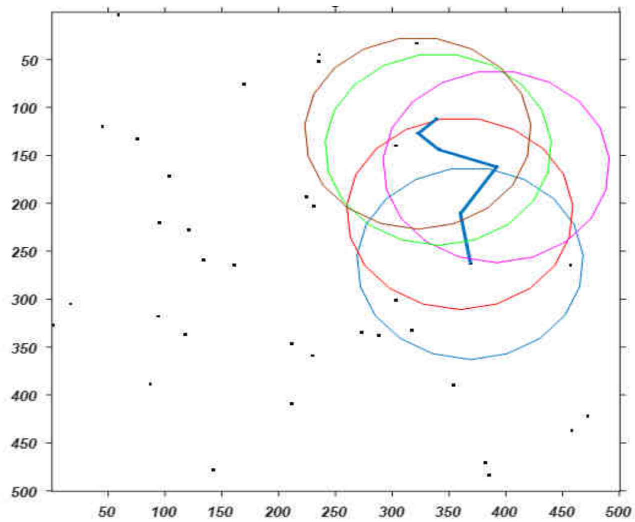


Fig. 4. Active Communication using Omnidirectional Antenna

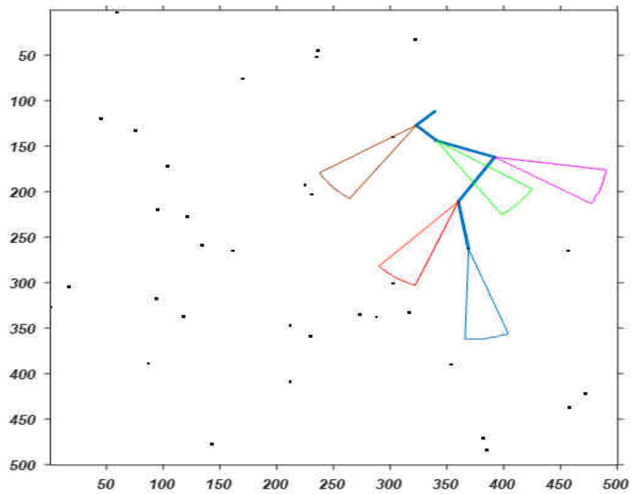


Fig. 5. Active Communication using Smart Antenna

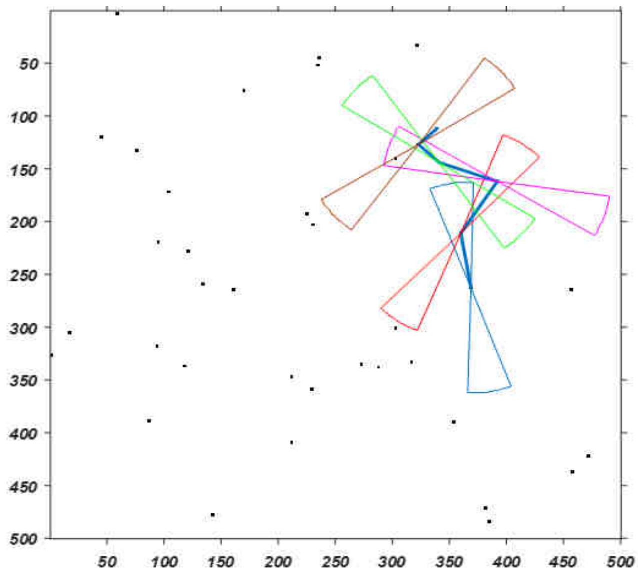


Fig. 6. Active Communication using Smart Antenna with bi beam activated

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.

From figures, the ability of smart antennas to direct their radiation energy toward the direction of the intended node while suppressing interference can significantly increase the network capacity compared to a network equipped with omnidirectional antennas because they allow the communication channel to be reused. In other words, nodes with omnidirectional antennas keep the neighboring nodes on standby during their transmission while nodes with smart antennas focus only on the desired nodes and allow the neighboring nodes to communicate. Therefore, smart antennas together with efficient access protocols can provide high capacity as well as robustness and reliability to wireless sensor networks and allows a better communication between nodes.

C. Gain

In this part we compared the obtained gain with node occupied by a smart antenna composed of six elements and node occupied by an omnidirectional antenna. Table 1 demonstrate value of gain in different desired direction. Taking the static following communication Fig. 8 between nodes for transforming the message, such as: the second node B located in the direction 100 from A the first node, the third node C located in the direction 55 from B, the fourth node D located in the direction 150 from C, the fifth node E located in the direction 140 from D, the BTS located in the direction 45 from E.

The expression of the gain is given as follow [11]:

$$G(\theta) = 4 * \pi * \frac{AF^2(\theta)}{\iint_\Omega AF^2(\theta,\phi)d\Omega} \quad (4)$$

Where $d\Omega = \sin(\theta) * d\theta * d\phi$ the solid angle and AF is the array function.

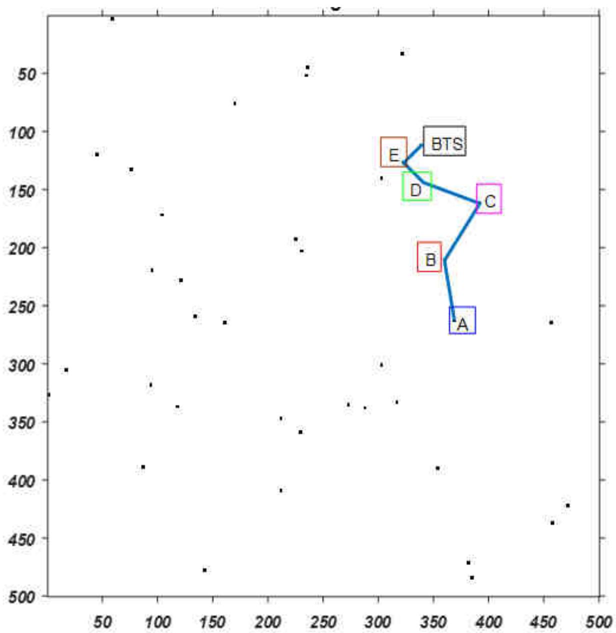
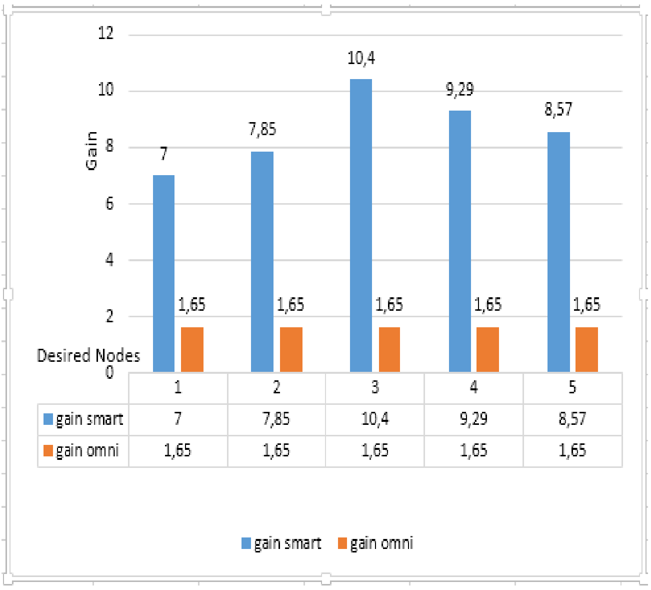


Fig. 7. Static communication between nodes

Fig. 8 show Total Gain of Smart Antenna System in a given direction is bigger and significant than an Omnidirectional Antenna System, because omnidirectional antenna radiates or receives equally well in all directions. Fig 9. Shows comparison of gain in different array element configuration. By increasing the number of elements employed in the array the gain can be improved.



	1	2	3	4	5
gain smart	7	7,85	10,4	9,29	8,57
gain omni	1,65	1,65	1,65	1,65	1,65

Fig. 8. Total Gain according to direction

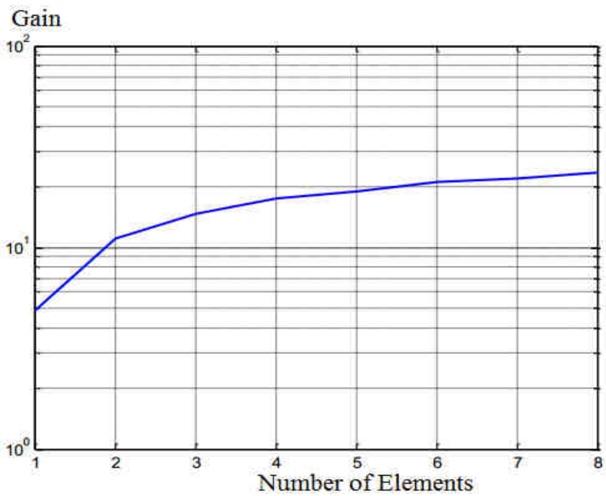


Fig. 9. Comparison of Gain in different array elements comfiguration.

III. CONCLUSION

In this paper, some advantages on potentialities of integration of smart antenna system in wireless sensor networks nodes. The performance metrics are plotted and the comparison between the WSN using SAS and the OAS is obtained. Through simulation results we observed that using SAS provide better communication between nodes as compared to OAS. The gain is also higher in SAS implementation than omnidirectional antenna system.

REFERENCES

1. Frank B. Gross. “Smart Antenna for Wireless Communication with Matlab”. McGraw-Hill Companies, Inc. United States of America 2005.
2. C.A. Ballanis. “Antenna theory analysis and design”. 3rd edition, John willey and Son’s Inc, New York 2005.
3. Luca Catarinucci, Sergio Guglielmi, Riccardo Colella, Luciano Tarricone . “Switched-Beam antenna for WSN nodes enabling Hardware-driven power saving”. Proceedingsof the 2014 federated conference on computer science and information systems pp. 1079-1086 . DOI: 10.15439/2014F82 ACSIS, Vol. 2
4. Luca Catarinucci, Sergio Guglielmi, Luigi Patrono, Luciano Tarricone

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.

. "Switched-Beam antenna for Wireless Sensor Networks nodes". Progress in electromagnetics research C, Vol. 39, 193-207,2013
5. G. Giorgetti, A. Cidronali, S.K.S. Gupta, G. Manes, "Exploiting LowCost Directional Antennas in 2.4 GHz IEEE 802.15.4 Wireless Sensor Networks", in Proc. 10th European Conference on Wireless Technology, Oct. 2007, pp. 217-220.
6. D.-C. Chang, B.-H. Zeng, J.-C. Liu, "Reconfigurable angular diversity antenna with quad corner reflector arrays for 2.4 GHz applications," IET Microw., Antennas Propag. , vol. 3, no 3, pp. 522–528, Apr. http://dx.doi.org/2009, 10.1049/iet-map.2008.0119
7. L. Ming-Iu, W. Tzung-Yu, H. Jung-Chin, W. Chun-Hsiung, J. ShyhKang, "Compact Switched-Beam Antenna Employing a Four-Element Slot Antenna Array for Digital Home Applications, " IEEE Trans. Antennas Propag. , vol. 56 , no.9, pp 2929-2936, Sept. 2008.
8. Tian-Hong Loh, Ke Liu, Fei Qin, Haitao Liu . "Assessment of the adaptive routing performance of a wireless sensor network using smart antennas". IET wireless sensor systems, 5th November 2014, DOI: 10.1049/iet-wss.2014.0066.
9. A. A. Ansari, "Performance Comparison for Omnidirectional and Directional MAC Protocols for Ad hoc Network," Int. J. Comput. Appl., vol. 70, no. 21, pp. 26–31, 2013.
10. R.Aouami.E.Said. M.Rifi and M.Ouzzif 'Fountain code enabled of IEEE 802.11DCF for optimazation throughput in Wireless Sensors The 10th International Conference for Internet Technology and Secured Transactions (ICITST-2015)', London, UK .14-16 December 2015.
11. M. N. Alam, M. A. Hussain, and K. S. Kwak, "Neighbor initiated approach for avoiding deaf and hidden node problems in directional MAC protocol for ad-hoc networks," Wirel. Networks, vol. 19, pp. 933–943, 2013.
12. M. Hanaoui, M. Rifi, H. Bouassam, H. Terchoune, "Improvement of energy efficiency of GSM BTS by using smart antenna system" Revue Méditerranéenne des Télécommunications, Vol. 5, N° 2, June 2015. ISSN 2458-6765

Mohamed HANAOUI, born in Taounate, Morocco in 1989. He received his license degree in science of physical matter from the sidi Mohamed ben Abdellah University, faculty of sciences Fez in the year 2011, and He received his master's degree in Science of the engineer option telecommunication and microwave devices from the University of Sidi Mohamed Ben Abdelah, National School of Applied Sciences Fez in the year 2013. His research activities covers several area of research fields such as signal processing, electromagnetic waves propagation, ElectroMagnetic Compatibility, Transmission Lines, Smart antenna, Sensor Networks.

Rachid AOUAMI, received his Mastrer degree in telecommunication and networks from the University Chouaib Doukkali of Eljadida. He is currently Ph.D.Student of compter sciences at Laboratory RITM (Networks, Computer, Telecom and Multimedia), CED Engineering SCiences in ENSEM school Casablanca .His research interests involve Wireless Sensor Networks, MTM, RFID, GreenTic, Smartphones, and Computer Networks.

Mounir RIFI, was born in Fez, Morocco in 1962. Now he is the Director of EST (Ecole Superieure de Technologie) at the University Hassan II of Casablanca and Professor of Higher Education, since 1987. He is also member of Doctoral Studies Centre "Engineering Sciences", Head of Research Team "Networks & Telecoms" and Director of the Research Laboratory: RITM (Networks, Computer, Telecom and Multimedia). Prof. Rifi obtained his PhD in Electronics, May 1987 (University of Lille - France). He is Board member of GREENTIC Casablanca association, founder and publisher of the Mediterranean Telecommunications Journal. His research activities covers several area of research fields such as electromagnetic waves propagation , ElectroMagnetic Compatibility, RFID, Transmission Lines, Smart antenna, Sensor Networks, Computer Networks.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.