An Overview of Applications, Standards and Challenges in Futuristic Wireless Body Area Networks

Ragesh G K[1], Dr.Baskaran K[2]

[1] Department of Computer Science and Engineering, Government College of Technology, Coimbatore-641013, Tamil Nadu, India

[2] Department of Computer Science and Engineering, Government College of Technology, Coimbatore-641013, Tamil Nadu, India

Abstract

Recent technical advancements in low-power integrated circuits, ultra low-power RF (radio frequency) technology, wireless communications and micro sensors allowed the realization of Wireless Body Area Networks (WBANs). It is one of the latest technologies in health care diagnosis and management. A body area network wirelessly connects independent nodes (e.g. medical devices, earphones, sensors, actuators) attached to the body surface, implanted into tissues/body, or dispersed in the clothing for applications in home/health care, sports, entertainment, defense, ambient intelligence, pervasive computing and many other areas. These sensors offer promising applications in areas such as real time health monitoring, interactive gaming and consumer electronics. WBAN does not compel the patient to stay in the hospital thereby giving much physical mobility. Thus it greatly increases the efficiency of a health care system. This paper presents an overview on the various aspects of WBAN including sensors used, applications, power efficiency, communication protocols, security requirements, existing projects in WBANs and challenges faced in wireless body area networks.

Keywords: *Wireless body area network, WBAN, body area network, real time health monitoring, bio sensor networks, wearable sensors.*

1. Introduction

The growing cost of healthcare and the aging population in developed countries have introduced great challenges for governments, healthcare providers and healthcare industry. There is great interest in using emerging wireless technologies to support remote patient monitoring in an unobtrusive, reliable and cost effective manner thereby providing personalized sustainable services to patients. Wireless Body Area Networks (WBANs) is one such emerging technology that has the potential to significantly improve health care delivery, diagnostic monitoring, disease-tracking and related medical procedures. A crucial aspect of WBANs is their ability to provide highly reliable communications for medical devices, especially those implanted in the human body. Wireless Body Area Network (WBAN) consists of a number of inexpensive, lightweight, miniature sensors which could be located on the body as tiny intelligent patches, integrated in to clothing or implanted beneath the skin or embedded deeply in to the body tissues. Their main purpose is to enable doctors and other medical staff to safely monitor the health status of patients. This WBAN technology brings affordable and efficient healthcare solutions to people that will improve their quality of life.

Strategically placed wearable or implanted wireless sensor nodes consistently monitor the patient's vital signs, such as electro cardiogram (ECG), EEG and blood pressure; or important environmental parameters like temperature and humidity. The patient related data (gathered data) from all WBANs may ultimately be sent to a centralized healthcare repository for permanent records. Physicians can remotely access this data to assess the state of health of the patient. Additionally the patient can be alerted using SMS, alarm, or reminder messages. In this article we present a survey of the state of the art in Wireless Body Area Networks. Our aim is to provide a better understanding of the current research issues in this emerging field. The remainder of this paper is organized as follows. First, the sensors of WBAN are discussed in Section 1. Next, the applications of BANs and energy efficiency of WBAN are discussed in Section 2 and 3. Section 4 gives an overview of the standardized technologies used for WBAN communication. Section 5 deals with the necessity of security in WBAN. Section 6 and 7 deals with Physical and MAC layers. Section 8 discusses the WBAN specific routing protocols and other protocols related to WBAN. Relation to wireless sensor networks and WBAN challenges is treated in section 9 and 10. An overview of existing projects and social issues of

WBAN is given in Section 11 and 12 respectively. Finally section 13 concludes the paper.

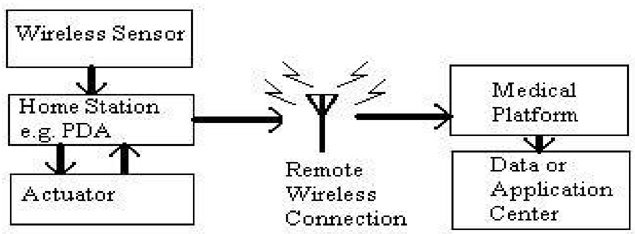

Fig.1 Data flow in a typical medical BAN

2. Sensors of WBAN

The sensors of a Body Area Network are extremely compact and complex in design. The fact that the sensors are so minute means that the patients will be able to lead a normal life, as the sensor devices are very unobtrusive. All sensors produced will contain the same basic elements such as a power supply and wireless transceiver as well as a control mechanism, a sensor and the casing that will hold all of the components together. The sensors will be designed in a way that allows them to be self-governing for the entire lifetime. BAN's work through a process of data being transmitted from an implanted device to an external device. The sensor which is implanted inside a patient's body interacts with other sensors and actuators wirelessly. The mechanism by which an agent acts upon an environment is known as an actuator. Artificial intelligent agent or any other autonomous being (human being or an animal) can be an agent. The Body Area Network functions by passing data from each sensor to a main station. The main station then fuses the data passed from each of the sensors and it is then sent to a recipient via the internet.

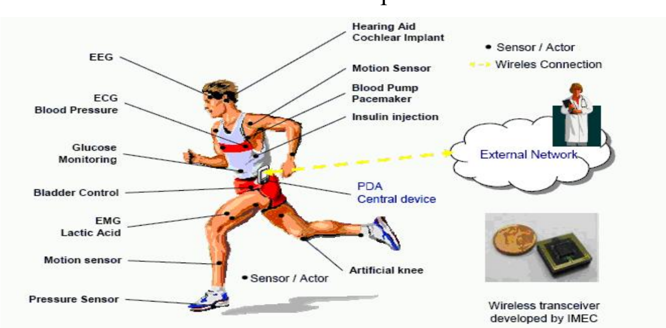

Fig.2 A BAN on an Athlete (Latré, 2005)

2. Applications of BANs

Due to the diverse components that can be connected and integrated, body area networks will be able to provide various functions in healthcare, emergency, work, research, lifestyle, sports, or military.

2.1 Medical Applications

BANs can provide interfaces for diagnostics, for remote monitoring of human physiological data, for administration of drugs in hospitals and as an aid to rehabilitation. In the future it will be possible to monitor patients continuously and give the necessary medication whether they are at home, in a hospital or elsewhere. Patients will no longer need to be connected to large machines in order to be monitored.

2.2 Lifestyle and Sports

BANs enable new services and functions for wireless body-centric networks including wearable entertainment system (e.g., music entertainment), navigation support in the car or while walking, museum or city guide, heart rate and performance monitoring in sports, infant monitoring, wireless cash card (e.g., display of recent transactions and checking of balance, etc).

2.3 Military Applications

The opportunities for using BANs in the military are numerous. Some of the military applications for BANs include monitoring health, location, temperature and hydration levels. A battle dress uniform integrated with a BAN may become a wearable electronic network that connects devices such as life support sensors, cameras, RF and personal PDAs, health monitoring GPS, and transports data to and from the soldier's wearable computer. The network could perform functions such as chemical detection, identification to prevent casualties from friendly fire and monitoring of a soldier's physiological condition. Calling for support, his radio sends and receives signals with an antenna blended into his uniform. As a result, BANs provide new opportunities for battlefield lethality and survivability.

3. Energy efficiency

Major sources of energy waste usually considered are: idle listening, over hearing and protocol overhead. A node is idle listening when it expects to receive packets and no packets are received. Listening is an expensive operation, and this should be avoided. A node is overhearing when it receives irrelevant packets. This wastes energy, because receiving is an expensive operation as well, nodes should only receive relevant packets. Protocol overhead is the ratio of the amount of bits needed to transmit a data packet over the amount of bits of data packet itself. This will always be present, but should be kept to a minimum.

4. Technologies and Standards

A number of standardized technologies are related to WBAN research.

4.1 IEEE802.15.6

The IEEE 802.15 task group 6(BAN) is developing communication standard optimized for low power devices to provide a variety of applications including remote health care monitoring, consumer electronics, interactive gaming and other. Existing ISM bands as well as frequency bands approved by national medical and/or regulatory authorities can be used by this standard. The standard requires support for Quality of Service (QoS), extremely low power, and data rates up to 10 Mbps.

4.2 IEEE 802.15.4

Some researchers consider this as a MAC protocol and lots of research focuses on this protocol. However, research points out that the performance of IEEE802.15.4 is not sufficient for WBANs. The performance of this protocol in a multi hop environment is very poor.

4.3 Bluetooth

Bluetooth is a broadly available WPAN protocol and is very popular for current medical care solutions, especially because of the large range of available hardware implementations. However Bluetooth and other WPAN protocols have been designed for high data rate networks and large battery capacity which does not match the WBAN requirements. Also lowering the data rates will increase the protocol overhead.

5. Security Requirements

The use of wireless technology, especially to deliver health care, also brings with it a host of concerns about security and privacy. The security mechanism of the system is responsible for providing the following security services on specified biomedical data when requested to do so by the applications.

Data Encryption—the data is encrypted so that it is not disclosed whilst in transit. Data encryption service provides confidentiality against eavesdropping attacks.

Data Integrality—Data integrality service consists of data integrity and data origin authentication. Proper data integrity mechanisms at the BN and the BNC ensure that the received data is not altered by an adversary.

Freshness Protection—Data freshness ensures that the data frames are in order and are not reused.

Authentication— an efficient method against impersonation attacks.

6. Physical layer

A lot of research has investigated to physical layer. At the beginning of WBAN research a number of authors proposed Ultra Wide Band (UWB) as a physical layer for WBANs.UWB has the advantage of low energy consumption, good co-operation with existing wireless networks and a range large enough to support the entire body. Due to standardization issues and difficulties delivering the very high speeds.UWB does not progress well. As opposed to the wide bands proposed by UWB, other researchers propose the small, Industrial, Scientific and Medical (ISM) bands of the IEEE 802.15.4 and IEEE802.15.6.Current most working WBAN prototypes are based on ISM bands.

7. MAC layer

A number of WBAN specific MAC protocols exist. These can be divided in to single hop and multi hop protocols. The latter refers to the protocols which are optimized for multi hop topologies. The first protocols were designed based on a single hop topology. An example for this is Heart Beat driven MAC (H-MAC), which uses the heart beat to synchronize nodes. The protocol is specifically designed for WBANs; however traffic adaptations is not possible. Few other protocols have been developed usually IEEE 802.15.4 is preferred. Because of the dynamic nature, ad hoc network protocol could also be considered as WBAN protocols. Ad hoc network protocols are based on always –on radios, which matters their application to WBAN unfeasible.

8. WBAN specific routing protocols

When considering wireless transmission around and on the body, important issues are radiation absorption and heating effects on the human body. To avoid the heat generation, five thermal aware routing protocols were proposed. To reduce tissue heating, the radio's transmission power can be limited or traffic control algorithms can be used. Researchers showed that the bio effects caused by radio frequency radiation are highly related to the incident power density, network traffic and tissue characteristics. A price-based rate allocation algorithm further shows that the bio effects can be reduced via power scheduling and traffic control algorithms. The Thermal Aware Routing Algorithm (TARA) routes data away from high temperature areas due to focusing data communications, defined as hotspots. When the temperature of a neighboring node is above a certain threshold, i.e., the node is becoming a hot spot, the packets will no longer be forwarded to the node but will be withdrawn and rerouted through alternate paths. The algorithm leads to a better temperature distribution over all the nodes in the network. However, TARA only considers the temperature as a metric. Consequently, it suffers from low network lifetime, a high ratio of dropped packets and low reliability, which is problematic for a WBAN. Improvements of TARA are Least Temperature Routing (LTR) and Adaptive Least Temperature Routing (ALTR). Unlike TARA, LTR always chooses the neighboring node with the lowest temperature as the next hop for routing. In order to maintain the network bandwidth, a predefined maximum hop count is used. When the number of hops exceeds this maximum, the packet is discarded. Loops are avoided by maintaining a list in the packet with the recently visited nodes. Unlike TARA, LTR always chooses the neighboring node with the lowest temperature as the next hop for routing. In order to maintain the network bandwidth, a predefined maximum hop count is used. When the number of hops exceeds this maximum, the packet is discarded. Loops are avoided by maintaining a list in the packet with the recently visited nodes. In general, temperature routing can be considered as a specific case of weight based routing. Results are promising, but reliability and energy efficiency can be hard to guarantee.

8.1 Other Routing Protocols

Similar to the related MAC protocols, a number of routing protocols for sensor and ad hoc networks could be considered good candidates for WBANs. The WSN protocols will focus on networks of a much larger scale while ad hoc network routing protocols will assume nodes with a larger battery and an always on radio.

9. Relation to Wireless Sensor Networks

In several papers, WBANs are considered to be a special type of WSN or Wireless Sensor and Actuator Network (WSAN) with its own requirements. However, traditional sensor networks do not tackle the specific challenges associated with human body monitoring. The most important difference is the need for reliable communication with each WBAN node, as opposed to the redundant character of WSN nodes. This corresponds to the typical medical application of WBANs, where only a single sensor per vital parameter is used. Moreover, the scale of WBANs is very small compared to typical large scale deployments of WSNs. In a WBAN, up to twenty nodes are expected to be deployed on a single person, while WSN protocols are usually designed for hundreds of nodes deployed in areas with diameters of hundreds of meters. A lot of research is being done toward energy efficient routing in ad hoc networks and WSNs. However, the proposed solutions are inadequate for WBANs. For example, in WSNs maximal throughput and minimal routing overhead are considered to be more important than minimal energy consumption. Energy efficient ad hoc network protocols only attempt to find routes in the network that minimize energy consumption in terminals with small energy resources, thereby neglecting parameters such as the amount of operations (measurements, data processing, access to memory) and energy required to transmit and receive a useful bit over the wireless link.

The following illustrates some main differences between Wireless Body Area Networks and Wireless Sensor Networks:

There are no redundant devices in WBANs in- spite of WSNs. All nodes in the network must be highly robust, reliable, and accurate. The lost information from one node often cannot be recovered by other nodes.

Because of the special features of the environment in which the WBAN operates (human body) the data loss is more significant. The signals of the sensors, specially the implanted ones, are considerably attenuated because the propagation of the waves takes place in or on a very lossy medium. Proprietary mechanisms may be required to ensure the QoS and real time data interrogation capabilities. However, in WSNs the data loss may be covered by other sensors.

The sensors which are either implanted into a tissue or attached on the surface of body must be very small in size to support unobtrusive monitoring of the patients. However, in WSNs the sensor size is not the main concern though smaller sensors are preferred. The small size of the WBAN sensors severely affects the power resources of the devices. The power supply recharge of the devices is often impossible. Thus, a long lifetime of the sensors is required.

The sensors in a WBAN are located in or on the human body which can be in motion. This challenge for WBAN is rarely available for WSNs. Thus the WBAN must be robust against the high probable network topology changes. In addition, biological variation and complexity cause a more variable structure.

10. WBAN Challenges

Challenges	WBAN
Scale	As large as human body parts(millimeters/centimeters)
Node Number	Fewer, more accurate sensors nodes required (limited by space)
Node Function	Single sensors, each performs multiple tasks
Node Accuracy	Limited node number with each required to be robust and accurate
Node Size	Pervasive monitoring and need for miniaturization
Data Protection	High level wireless data transfer security required to protect patient's information
Access	Implantable sensor replacement difficult and requires biodegradability
Bio Compatibility	A must for implantable and some external sensors. Likely to increase cost
Context Awareness	Very important because body physiology is very sensitive to context change
Wireless Technology	Low power wireless required, with signal detection more challenging
Data Transfer	Loss of data more significant, and may require additional measures to ensure QoS and real-time data interrogation capabilities

Table.1 Challenges faced by WBAN

11. Existing WBAN Projects

In the recent years a lot of work related to WBANs has appeared in the literature. The attempts are mostly focused on proposing solutions for the issues of the WBANs. Before introducing the IEEE 802.15.6 standard by the IEEE 802.15 Working Group the structure of WBANs and protocols and mechanisms of the physical layer and MAC sub layer of WBANs have been one of the most important concerns which attracted attention of many researchers. There are currently several research groups throughout the world which focus on design and implementation of a WBAN. The researchers have employed different wireless technologies in their projects in the field of wireless short-range connectivity, such as the IEEE 802 family of WPANs, WLANs, Bluetooth and Zigbee. Due to major drawbacks of other WPAN and WLAN solutions the IEEE 802.15.4/ Zigbee system has been the most favoured approach in the existing projects before the IEEE 802.15.6 standard is introduced.

In [4] proposes a system that could perform real-time monitoring of complex conditions on streaming data from various body sensors within a Wireless Body Area Network (WBAN). The system enables personal medical applications to be developed using personal electronic devices combined together with sensors in a WBAN. The main techniques developed are the query language which supports windowing capabilities, and the query index using an Interval Skip List data structure with windowing support.

In[6] *Stevan Marinkovic and Emanuel Popovici* developed implemented and tested a Nano power Wake Up Radio mainly intended for Wireless Body Area Networks (WBANs), but it can be also used in other types of low power wireless networks. The radio was tested for power consumption and robustness to communication interferences from a wireless device commonly found around the person carrying a WBAN.

Janani.K, V.R.SarmaDhulipala and R.M.Chandrasekaran developed a *WSN based frame work for human health monitoring in* [7].In this paper the framework they proposed provides a clear understanding how WSN is used for remote monitoring of the patient's health. The paper mainly focus on the understandability of the remote patient monitoring done in hospital, the vital network parameters to be considered, scalability and power consumption.

Jae-Hoon Choi, Heung-Gyoon Ryu of Chungbuk *National University, Korea proposed a* new QAPM (*Quadrature-Amplitude-Position-Modulation*) scheme for improving power efficiency in [8]. In this paper, they were analyzed existing PSSK and new propose QAPM scheme. The PSSK and QAPM scheme are extension method for increase power efficiency. And the simulation results, shows that BER performance of QAPM and PSSK better than QAM and PSK in AWGN channel. Also throughput of QAPM has better throughput characteristics in low SNR than PSK, QAM and PSSK.

In Opportunistic Routing for Body Area Network [9] provides an opportunistic scheme to exploit the body movements during the walking to increase the life time of the network. In this work they exploited the motion of the body parts to increase the lifetime of the network. To evaluate the performance of the proposed scheme, the energy consumption of the network per bit for the single hop, multi-hop using relay node and the opportunistic scheme are compared. The results shows the proposed scheme can increase the life time of the network by decreasing the energy consumption in both the sensor and relay nodes while maintaining the same BER as the other two schemes.

In *Wearable ECG Monitor* project [10] a wearable ubiquitous healthcare monitoring system using integrated electrocardiogram (ECG), Photoplethysmogratphy (PPG), Skin Temperature and Accelerometer etc. were designed and developed. In this design, nonintrusive healthcare system was designed based on WBAN for wide area coverage with minimum battery power to support RF transmission. In this system, WBAN, Zigbee, is used to communicate between wearable physiological signal devices and the personalized mobile system. We have developed various devices such as a wearable chest, wrist and necklace Device. The wearable ubiquitous healthcare monitoring system allows physiological data to be transmitted in wireless sensor network for Mobile network.

In [11] *Mrinmoy Barua, M.S. Alam, Xiaohui Liang, and Xuemin (Sherman) Shen* an efficient secure data transmission scheme in WBAN is proposed with data integrity. The scheme is user-centric and the secure key is shared among all sensors in a WBAN to minimize any additional memory and processing power requirements. Security analysis and numerical results demonstrates that the scheme can minimize the mean waiting time of a real-time traffic in WBAN and provide proper security and privacy.

Xigang Huang, Hangguan Shan, and *Xuemin (Sherman) Shen* investigate the energy efficiency of cooperative communications in wireless body area network (WBAN) in [12]. Three transmission schemes had been compared in this paper. Direct transmission, single-relay cooperation, and multi-relay cooperation. For each of them, they analyzed its outage performance and studied the problem of optimal power allocation with the constraint of targeted outage probability.

12. Social Issues

A number of issues exist regarding the creation of BANs include system design issues and human issues. System Design Issues include (Jovanov, 2005):

- Sensor Types

What type of sensor should be included in the BAN? This will depend on where it is to be used and for what purpose

- Power Sources

If the BAN is designed to be used for a long period of time then the power sources must be appropriate. If it is going to be used for some short intense activity then a different source could be used.

- Wireless Communication Range

Is the person using the BAN likely to remain within a particular area? e.g.: a hospital, or are they likely to be outdoors? E.g.: a soldier in the desert.

- Sensor location and mounting

Could they be woven into the uniform of a solider or might they need to be small unobtrusive implants in the skin?

- Weight and size of sensor

If the person is confined to bed at home then the sensors could be of a different type from those used on a runner.

13. Conclusion

In this paper various key aspects of WBAN including sensors used, application areas, technologies and standards, routing protocols, WBAN challenges and existing WBAN projects are outlined. Also discussed energy requirements, security requirements and issues present in various layers of WBAN. Finally some of the social issues related to WBAN application are mentioned. There are many challenges that still need to be addressed, especially on high bandwidth and energy efficient communication protocols, interoperability between BANs and other wireless technologies, and the design of successful applications. Future work will be concentrating on the design of a context aware mechanism which will carefully optimize security, safety and usability.

References

[1]Maulin Patel and Jian Feng Wang, “Applications, Challenges and Prospective In Emerging Body Area Networking Technologies”, IEEE Wireless Communications, IEEE, 2010,pp. 1536-1284.

[2] Ming Li and Wenjing Lou “Data security and Privacy In wireless body area networks”, IEEE Wireless Communications, February 2010,pp. 1536-1284 .

[3] Xigang Huangy, Hangguan Shany, and Xuemin Shen, “On Energy Efficiency of Cooperative Communications in Wireless Body Area Networks”, IEEE,2011.

[4] Minsoo Lee, Okju Choi, Seul-A Lee and Nory Chou, “Real time monitoring of complex window conditions on Body sensor data for wireless body area networks”,IEEE International Conference on Consumer Electronics (ICCE), 2011.

[5]Saeed Rashwand, Jelena Misic and Hamzeh Khazaei, “Performance Analysis of IEEE 802.15.6 under saturation condition and error prone channel,” IEEE. WCNC-Network, 2011.

[6]Stevan Marinkovic and Emanuel Popovici “Nano- Power Wake-Up Radio Circuit for Wireless Body Area Network”, IEEE,2011.

[7] Janani.K, V.R.SarmaDhulipala and R.M .Chandra Sekaran "A WSN based frame work for human health monitoring", International Conference on devices and communication, IEEE, 2011.
[8] Jae-Hoon Choi and Heung-Gyoon Ryu "A QAPM Quadrature Amplitude-Position-Modulation) scheme for improving power efficiency", IEEE, 2011.
[9] Arash Maskooki, Cheong Boon Soh, Erry Gunawan and Kay Soon Low , "Opportunistic Routing for Body Area Network", 1st IEEE International Workshop on Consumer eHealth Platforms, Services and Applications, IEEE,2011.
[10] Youngsung Kim, Il-yeon Cho, "Wearable ECG Monitor-Evaluation and Experimental Analysis", IEEE,2011.
[11] Mrinmoy Barua, M.S. Alam, Xiaohui Liang, and Xuemin (Sherman) Shen, "Secure and Quality of Service Assurance Scheduling Scheme for WBAN with Application to eHealth", IEEE WCNC 2011 –Network,2011.
[12] Xigang Huang, Hangguan Shan, and Xuemin "On Energy Efficiency of Cooperative Communications in Wireless Body Area Networks‖, IEEE WCNC 2011 –Network,2011.
[13] D. Cypher, N. Chevrollier, N. Montavont, and N. Golmie-"Prevailing over wires in healthcare environments: benefits and challenges," IEEE Communications Magazine, vol. 44, no. 4, Apr. 2006. pp. 56{63.
[14] S. Drude-"Requirements and application scenarios for body area networks," in Mobile and Wireless Communications summit 2007. 16th IST, Budapest, Hungary, Jul. 2007, pp. 1{5.
[15] M.A. Ameen, Ahsanun Nessa and Kyung Sup Kwak, "QoS issues with focus on Wireless Body Area Networks", Third 2008 International Conference on Convergence and Hybrid Information Technology, IEEE,2008.
[16] M.Umar Talha and Jahanzeb Ahmad, "Body Area Networks (BANS) – An Overview With Smart Sensors Based Telemedical Monitoring System",Iraq university, Karachi.
[17] Latré, B. Moerman, I., Dhoedt, B, Demeester, P. "Networking in Wireless Body Area Networks", http://www.ibcn.intec.ugent.be/css_design/research/topics/2005/Networking/Wireless/Body/Are/Networks.pdf, 2005.

Ragesh G K
Ragesh G K obtained his B.E degree in Electronics and Communication Engineering from Anna University, Chennai, Tamil Nadu, India in 2005 and his M.E degree in Communication systems in 2008 from Anna University, Chennai, Tamil Nadu, India. Currently he is a Research scholar in Department of computer science and engineering at Government College of Technology, Coimbatore, Tamil Nadu, India. His research interests include Bio sensor networks, wireless sensor networks, Mobile ad hoc networks and Network security.

Dr.K.Baskaran
Dr.K.Baskaran is a member of the IEEE and ISTE, obtained his PhD degree from Anna University, Chennai. Tamil Nadu, India. He is having 18 years of teaching experience and got several awards including Best System Paper Award from IETE in 2010.Currently he is working as an Associate Professor in Department of computer science and engineering at Government College of Technology, Coimbatore, Tamil Nadu, India. His research interests include MANETs, Wireless sensor networks, Cloud Computing, Wireless Body Area Networks and Network security.