

# Networking in Wireless Body Area Networks

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*Abstract*— The increasing use of wireless networks and the constant miniaturization of electrical devices has empowered the development of a Wireless Body Area Network (WBAN), which is a wireless network of devices attached to or implanted into the human body. A WBAN imposes specific requirements on the network such as an extremely low transmit power to minimize the energy consumption, and hence maximize the lifetime, and to minimize the heating of the surrounding tissue. Tackling these challenges, energy efficient and reliable multi hop routing protocols will be developed.

*Keywords*— Body Area Networks, routing, energy efficient, networking

## I. INTRODUCTION

RECENT advancements in electronics have enabled the development of small and intelligent (bio) medic sensors which can be attached to or implanted into the human body. Due to the multitude of sensors, the use of wires to extract data from the sensors is getting too cumbersome. As a solution, the sensors placed on and inside the body are equipped with a wireless interface which enables an easier application. In this manner, a new type of network can be defined: a Wireless Body Area Network or WBAN.

A Wireless Body Area Network consists of several small and mobile devices close to, attached to or implanted into the human body [1]. These devices communicate by means of a wireless network. Interaction with the user or other persons is generally handled by a central device, e.g. a PDA. We distinguish two types of devices: sensors and actuators.

The sensors are used to measure certain parameters of the human body. This can be done externally or internally. Examples of external monitoring include measuring the heartbeat, blood pressure, body temperature, recording a prolonged ECG, ... Internal measurements through implanted medical sensors encompasses monitoring of the cerebral activity for epileptic patients, measuring the glucose levels in the blood of diabetics, endoscopy using a sensor integrated into a pill, retina prostheses for the visually impaired existing of a matrix of micro sensors that transform electrical signals into neurological signals and thus mimic the normal behavior of the retina, microphone, headphone, digital glasses with the functionality of a PC monitor, ...

The actuators or actors on the other hand take some specific actions according to the data received from the sensors or through interaction with the user. Some examples of actuators are: a device equipped with a built-in reservoir and pump for administering the correct dose of insulin to diabetics based on the measurements of glucose level received from the sensors; intravenous administering of medication upon detection of a higher

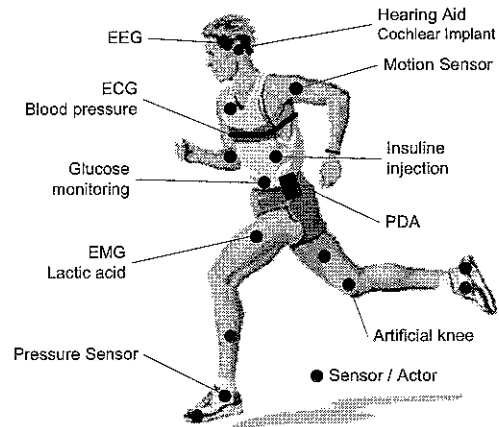


Fig. 1. A Wireless Body Area Network

cerebral activity, hereby preventing an epileptic seizure; changing the image of the digital glasses, ...

In general a (WBAN) can be utilized to provide interfaces for the disabled, for diagnostics, for drug administration in hospitals, for telemonitoring of human physiological data, as aid for rehabilitation, etc. It will be possible in the future to monitor patients continuously and to apply the necessary medication, whether it is in a hospital or at home or during transportation. Patients will no longer need to keep to their beds, but will be able to move about freely. An example of a Wireless Body Area Network is given in Fig. 1.

## II. CHALLENGES

A WBAN imposes great demands on the network:

- The devices used have limited energy resources available as they are very small (often less than 1 cm<sup>3</sup>). Furthermore, for most devices it is impossible to recharge or change the batteries although a long lifetime of the device is wanted (up to several years or even decades for implanted devices). Hence, the energy resources and consequently the computational power and available memory of such devices will be limited;
- The network consists of numerous devices in and on the body which are in each others vicinity. In order to minimize the heating of the surrounding tissue and the interference between the devices, a low transmit power is required;
- The devices are located on the human body that can be in motion. WBANs should therefore be robust against frequent changes in the network topology;
- The propagation of the waves takes place in or on a (very) lossy medium like the human body. As a result, the waves are attenuated considerably before they reach the receiver;
- And finally the devices are often very heterogeneous and may have very different demands or may require different resources of the network in terms of data rates, power consumption and

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reliability.

Currently no network protocols that meet (most of) the aforementioned requirements exist as the research in the region of Body Area Networks is quite recent. Current projects focus mainly on radio interfaces and sensors and use a star network where the sensors or actuators have a direct wireless connection to the central device.

The objective of our research is the development of reliable and energy-efficient network protocols for Wireless Body Area Networks. Several layers will be addressed: the datalink layer, the network or routing layer, the transport layer and the application layer. As a final step, a cross-layer optimization of the network protocols will be implemented. In stead of reaching a sub-optimal solution were each layer is treated independently, an optimal solution can be found when the interactions between the layers are exploited.

### III. ROUTING LAYER

An approach to lower the energy consumption is the introduction of multi hop communication in stead of direct communication. In the latter, the device sends his data directly to the destination, which is often the central device. In multi hop communication the data is routed through intermediate devices which act as routers. An example can be seen in Fig. 2.

We will explain the energy gain through an example. In wireless networks, the transmitted power drops off with  $d^n$  where  $d$  is the distance between sender and receiver and  $n$  the path loss. Research at INTEC [2] has derived a path loss for WBANs ranging from 4 to 5.8 in a worst case scenario. Assume the path loss is 5 and that we have 3 sensors equidistantly placed on 1 line (Fig. 2). The power needed to send data can be modeled as  $\alpha d^5$ . To send data directly from node 1 to the central device a transmission power of  $\alpha \cdot (3 \cdot d)^5$  is needed. Using multi hop, we get a power consumption of  $\alpha \cdot 3 \cdot d^5$ , which means a reduction of 81! However, the used definition of power consumption is rather simple as it doesn't consider the static part of energy consumption. A more accurate model [3] which includes receiving and computation power consumption was used to compare single and multi hop communication. The results are shown in Fig. 3. The value of the loss coefficient was varied and it can be clearly seen that multi hop proves to be more energy efficient in a WBAN.

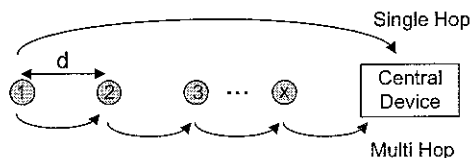


Fig. 2. Multi hop routing and single hop routing compared.

In order to use multi hop routing more effectively, relay devices can be introduced which merely act as routers and have no sensor or actor functionality. Relay devices can have more energy or more processing power available. The optimal position of possible relay devices will be strongly influenced by the properties of the physical layer. In this respect and in order to obtain an energy efficient network topology, the devices also need to

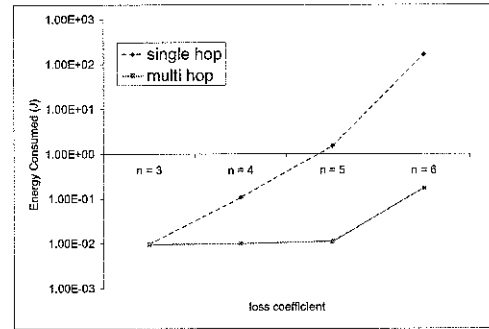


Fig. 3. Energy consumption of multi hop routing and single hop routing when 3 relay devices are used.

be able to tune the transmit power, involving an interaction between network layer and physical layer. Also interaction with the application layer will be studied, e.g. should the measured data be processed in the devices or should specialized devices be used.

To reduce the power consumption even more, new principles from the world of sensor networks such as aggregation of data, attribute-based addressing and data-centric routing could be used [4].

### IV. OTHER LAYERS

Once we have tackled the routing layer, the other layers can be optimized. Concerning the datalink layer, a possible approach is to work out a MAC protocol with a smaller send range (implying a lower transmit power) that uses the available energy more efficiently (by using for example energy-saving modes that control the on/off switching of the transceiver) and generates minimum control-overhead. The transport layer on the other hand will ensure the reliability of the communication. In a final stage, a cross layer protocol will be presented which incorporates the different layers.

### V. CONCLUSION

In this paper we have presented a framework to develop energy efficient network protocols for Wireless Body Area Networks. The use of single hop versus multi hop was evaluated and the results indicate that multi hop routing is more energy efficient.

### ACKNOWLEDGMENTS

This research is partly funded by the Belgian Federal Science Policy Office through the IAP V/11 contract, by The Institute for the Promotion of Innovation through Science and Technology in Flanders (IWT-Vlaanderen) through the contract No. 020152 and a PhD. grant for B. Latré and by the Fund for Scientific Research - Flanders (F.W.O.-V., Belgium).

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