Journal of Telecommunications System & Management

Editorial Open Access

Wearable Wireless Networks for Internet of Humans: Trends and Challenges

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Interconnected internet of humans (IoH) is a new paradigm in which wearable wireless networks (WWN) are emerging as a key enabling technology. WWN is revolutionizing health-care, sports and fitness, rescue and emergency management, augmented reality, fashion, and many other applications [1]. Wearable wireless networks composed of various types of devices such as sensors, actuator, coordinators, and gateways etc., to realize on-body, body-to-body (B2B) and off-body wireless communication as shown in Figure 1. However, often these devices are severely constrained due to ultra-low power consumption, miniaturization, low processing and storage capabilities as well as low delay requirements, consequently, the reliability and quality-of-service of above mentioned applications are very challenging.

IEEE 802.15.6 standard [2] provides great flexibility, features and WWN-specific provisions which are necessary to be exploited in the future applications and products. In terms of maximum achievable throughput at narrowband, IEEE 802.15.6 standard can reach up to 680 Kb/s, while operating at maximum frequency and highest modulations order by considering all the overheads of the MAC and PHY layers [3]. This impose limits to the use of IEEE 802.15.6 standard in emerging applications such as augmented reality where transmission of high rate audio and video are necessary. However, since IEEE 802.15.6 standard provides ultra-low power consumption for both invasive and non-invasive devices and with the key security features. The great flexibility on the usage of multiple options at the PHY (i.e., human body communication, narrow band, and ultra-wideband) and at the MAC layer (scheduled access, beacon enabled/disabled, CSMA/CA, polling and posting) as shown in Figure 2. All these factors make the IEEE 802.15.6 standard as a viable option for WWN. This short communication is focused on the important cross-layers perspectives and challenges addressed by WWN and their potential solutions.

Typically, application layer specify the requirements of the given product or solutions and based on those requirements rest of the protocol stack is designed. In WWN, there are number of applications (as explained earlier), require unique and different functionalities, for example, the application requirements of health monitoring of athletes is very different than the chronic or elderly patients. Based on the specific applications, different types of sensors can be selected, and the number of required nodes can be tuned since these factors have direct implications on the network layer. The data rates requirements of each sensor will configure the MAC layer parameters. Therefore, based on the specific application, fine tuning and design can be achieved.

At the network layer, there are number of important questions, for example, which routing mechanisms (i.e., mobile ad-hoc networks-based such as reactive or proactive, data-centric and geographical locations based routing) are most suited for body-to-body communication?, which standard or technology (such as WiFi, WSN, Bluetooth or WBAN) are appropriate for WWN?. To address these questions, one of our recent studies [4], reflect that both WiFi and WBAN technologies are most effective for B2B, in particular WiFi with geographical based routing approach is the most effective for the higher packet reception ratio and lower energy consumption. These finding are true provided the location information is available, otherwise, WBAN technology with gradient based routing is the best alternate to satisfy reliability constraints. Concerning the data disseminating approaches using WBAN technology for body-to-body communication in WWN, recent study shows that the distributed mechanism is more efficient than cluster-based for the packet delays, whereas, for the successful packet reception ratio, clustered approach is much better than the distributed [5].

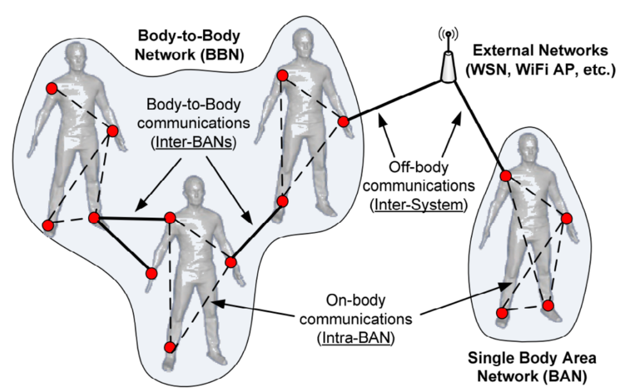

Figure 1: Wearable wireless networks: On-body, body-to-body and off-body wireless communication.

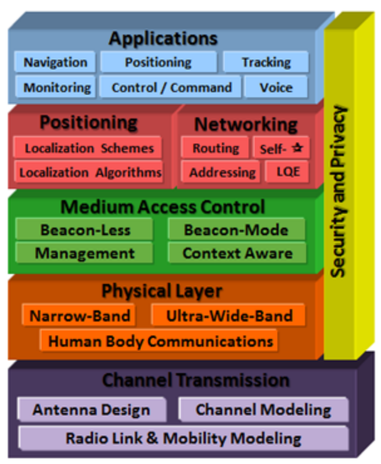

Figure 2: Wearable wireless networks protocol stack.

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Received August 28, 2015; **Accepted** September 02, 2015; **Published** September 04, 2015

Citation: Mahtab Alam M, Ben Hamida E (2015) Wearable Wireless Networks for Internet of Humans: Trends and Challenges. J Telecommun Syst Manage 3: e115. doi:10.4172/2167-0919.1000e115

In B2B communication, both co-channel and adjacent channel interference can disrupt the communication. In this regard, channel hopping and time shared coexistence schemes are very effective [6]. Although, time shared is more costly in terms of delay, but if the application is not delay constrained it can be considered. At the medium access control (MAC) layer, scheduled access is a viable option for the on-body communication, whereas in body-to-body communication since there are multiple coordinators, it becomes very complex to manage the superframes especially which coordinator to be selected as the leader that can control the beacon transmissions. In this regards multiple super frames can be used. On the other hand, CSMA/CA as a channel access technique is much simpler and can be implemented in a distributed fashion. It also provides much lower delay in comparison to scheduled access method.

Channel modeling is very active topic of research in both on-body and body-to-body communication [7-9]. Recently, body-to-body channel characterization and stochastic model is discussed [7], and the impact of short-term fading is analyzed in B2B communication. For effective on-body and body-to-body communication, accurate radio link and mobility modeling is vital. Most of the WWN nodes constantly vary over space and time which degrades the packet reception performance due to body shadowing and fading effects. Therefore, it is important to consider in the system design such models which take into account these factors and their effects. One of the options is to use deterministic approach for accurately estimating the pathloss and hence channel models can be much more accurate [10]. The physical layer of the emerging WWN applications are often required to be multi-standard compliant, typically, the on-body coordinator is selected for this purpose which can reach-out to the farthest nodes using powerful transceivers such as WiFi [11]. This is important in rescue and critical applications where end to end network connectivity is required.

Finally, IEEE 802.15.6 standard compliant radio transceivers are not yet commercially available which limits the product development and prototyping of WWN using IEEE 802.15.6 standard. However, efforts are such as [12,13], but fully functional compliant radios are expected to be available by end of 2015. Another open research challenges include the privacy and security. In this regards, initial studies such as [14,15], address the security vulnerability and personalized unobtrusive interactions solutions. However, the vision of secure WWN is still to be achieved where the devices would discover and recognize the authentic users while establishing a secure communication channel.

Acknowledgment

This publication was made possible by NPRP grant # [6-1508-2-616] from the Qatar National Research Fund (a member of Qatar Foundation). The statements made herein are solely the responsibility of the authors.

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