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Future Wireless Systems for Human Bond Communications

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Abstract In the near future the capability of the human beings to communicate sensations is going to be enhanced by incorporating the five sensory features in the messages and allowing more expressive and holistic sensory information exchange through communication techniques. The human bond communication (HBC) is currently a vision, but it is expected to become true. The objective of this paper is to give an overview of the potentiality and the main challenges for the adoption of HBC in the existing and future wireless systems. Starting from the HBC main features, a flexible architecture that could be considered for the development of these systems is described, highlighting how wireless systems could eventually boost the HBC adoption in different scenarios. The security and privacy issues are presented, focusing on the requirements and the new threats identification and proposing some possible solutions. Finally, some potential application contexts are analyzed and the open key issues for HBC implementation are addressed.

Keywords Human bond communications · Wireless systems · Network architecture · Security · Privacy

1 Introduction

One of the main goals of the future pervasive communication ecosystem is the improvement of the quality of our lives by increasing comfort and the enrichment of the interactions and conditions of our everyday activities [1]. In the near future this general objective is likely to encompass the capability of the human beings to communicate sensations by incorporating the five sensory features in the messages and allowing more

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expressive and holistic sensory information exchange through communication techniques [2]. However, even if it has been decades since communication technology has enabled the acquisition and transmission of aural and optical information by their auditory and optical senses, on the contrary the possibility to integrate the olfactory, gustatory, and tactile sensory features in the communications is still far from reality.

Nonetheless, the human bond communication (HBC) is a recently defined concept that incorporates olfactory, gustatory, and tactile sensation pursuing a more human sentiment centric communication for future network.

This paper aims to: (1) summarize the main features of the HBCs; (2) describe a flexible architecture that could be adopted in these future systems; (3) discuss how upcoming future wireless systems (e.g. upcoming 5G standards, Wireless Body Area Network, etc.) could eventually boost the HBC adoption; (4) deal with the security and privacy issues; (5) present the possible applications in multiple contexts; (6) address the open points in the development of an HBC system. The article is organized as follows. In the next subsections the HBC features and architecture are described and the role of HBC as a building block of the future communication ecosystem is discussed. In Sect. 2 the possible interaction between HBC and future wireless systems is addressed by highlighting how this relation could be beneficial. In Sect. 3 the security and resilience issues are dealt with, while in the Sect. 4 some of the possible HBC applications are presented. Finally, conclusions are drawn in the Sect. 5.

1.1 Human Bond Communication Features

The HBC has been recently defined [2] as a holistic approach to describe and transmit the features of a subject in the way humans perceive it; therefore, all the five senses are to be exploited in order to convey the physical subject into the information domain and allow its comprehension by two mutually agreed users of HBC. The comprehension of the information opens the way to the perception of the brain via neurotic pulses. As a consequence, the brain captures the sensed information from all the sense organs simultaneously and creates a perceptual image that has not only the visual property but other attributes like smell and taste. This complete description is stored in the brain to be accessed for future use.

To achieve the successful transmission of the human bond information via communication medium, we must have a system that should:

- sample and interpret the physical subject into the five sense domains;
- transform it into a data set and add encryption and other security add-ons;
- compress, code, modulate the data by highly efficient systems;
- transmit the data through a compatible medium;
- retrieve the information at the receiving side.

1.2 Human Bond Communication Architecture

A proposed baseline architecture which has been taken into account for HBC is reported in [2]. As depicted in Fig. 1, it consists of: (1) senducers (Sense Transducers) that perform sensory transduction of stimuli to electrical signals; (2) Human Bond Sensorium (HBS) that collects, processes and transmits the information and (3) Human Perceivable Transposer (HPT) that transposes the information.

A senducer is a module that is designed to:

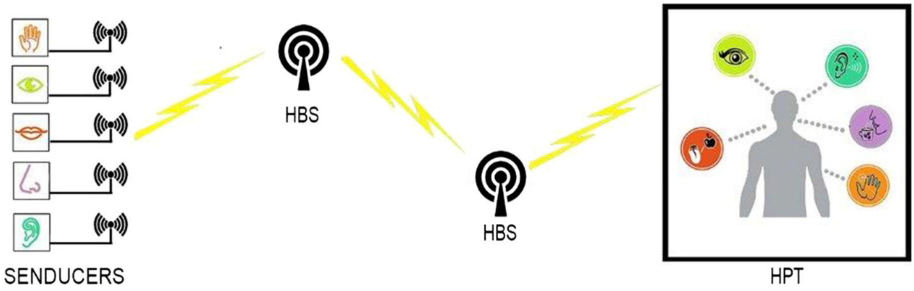

Fig. 1 HBC system architecture

- translate the subjects in the human sensing domains;
- optimize the sense and perception;
- communicate the data to the HBS.

It shall allow the system to construct the image of the subject with least possible fading. The senducers could be collective or co-located in the same monolith (Unoducers) or distributive in nature and panoramic.

In order to convey and transmit the information to a remote location, the senducers will be provided with HBS that is a common node that receives the sampled information, perform the most of processing (so permitting energy saving mechanism) and transmits the processed data. Among its tasks, the HBS provides data integrity, security, authenticity and reliability. More generally, HBS introduction can be seen as a step towards holistic communication systems.

The last entity of the HBC architecture is the Human Perceivable Transposer (HPT). Its role is to transpose the information received from HBS in human perceivable formats (i.e. into the sensory stimuli). HPTs produce stimuli that can be sensed by the observer's sense organs as detailed in [2].

1.3 HBC as a Building Block of Communication Ecosystem

Remote sensorial perception may appear advanced and futuristic but it represents a natural evolution of current communication systems. The complex interaction among all available senses, allows the user to access a multi-dimensional communication space, enabling new and unexplored opportunities.

The existing communication technologies may allow this new paradigm though an additional effort is needed to seamless integrate the available technological components and to define a robust and efficient communication system for the transport of sensed information.

As a matter of fact, to provide users with a realistic and complete sensory experience, effective HBC based smart communications shall rely on very high performance communication systems: particularly, in order to recreate the reality of the sensorial experience, the observing devices should be characterized by incisiveness and extensity. As described in [2], the incisiveness is the capability of a sense organ to detect and identify the small variations in the strength of a physical property, e.g. to describe which of the two rose is redder than another. Conversely, the extensity is the property of an organ to sense the large range of physical trait, e.g. human eye is able to perceive the colors of a very wide palette.

Moreover, beyond affording very high data rates, the underlying communication network must be stable and capillary. In the following, the future wireless communication systems will be analyzed in terms of their capabilities of satisfying the aforementioned requirements.

2 Future Wireless Systems as HBC Boosters

The technologies which are supposed to cooperate in the definition of the HBC systems are presented and described, aiming to identify their distinctive features which can afford their effectiveness and wide-spreading. Particularly, the 5G wireless systems, the localization techniques and Wireless Body Area Network (W-BAN) are considered as the technological components of the HBC which will permit to realize global applications and seamless services.

2.1 5G Communications

Next generation wireless system, which is defined as fifth generation or 5G, will be the ubiquitous ultra-broadband network enabling the Future Internet (FI): as described in [3] it will enable "full immersive (3D) experience" enriched by "context information" and "anything or everything as a service (XaaS)" and will open the way to a world where the network has been reduced to a ubiquitous "pipe of bits.". After the adoption of 5G systems, a revolution in the Information and Communications Technologies (ICT) field can be envisaged. In the framework of the HBC systems the traditional communication services, such as voice and video telephony, will be enriched by the specific information the senducers transmitt to the HBS. From the functional point of view, this solution will end up to redefine the network infrastructure as an extra-corporeal "nervous system".

In order to allow this visionary functionalities, the future HBC systems must cope properly with the extensity and incisiveness requirements previously introduced. It is worth underlining that with respect to the current wireless communications the future 5G communications shall guarantee the key performance indicator gains that are reported in Table 1.

In this context, the issues of connection, security, mobility, and routing management, will be effectively afforded. Full compatibility with current and future incremental 4G releases will be guaranteed by the possibility of instantiating any type of virtual architecture and installing any kind of network and service application efficiently.

Table 1 5G key performance gains

Key performance indicator	Gain to be afforded
Throughput	1000× more in aggregate, 10× more at link level
Latency	1 ms for robot remote control or tactile Internet applications, below 5 ms for the download of 2–8 K videos
Reliability	Ultra-high
Coverage	Suitable for a seamless experience
Battery lifetime	10× longer
Spectrum utilization	All spectra, from cellular bands to visible light

2.2 Localization

Accurate localization of the user is nowadays every important, both for delivering new smart services (location-aware) as well as for outdoor and indoor navigation. When the HBC concept will come true, the localization concept will be expanded to the positioning not only of the user, but also of the parts of the body as well as the relative position of the smart device on the body. Automatic device localization allows the smart devices to rapidly adapt to user's needs as well as interact autonomously with the body sensors. Different placements of the device on the body can be interpreted as the user's desire for an application or a major change in the human stimulus to be revealed or extracted.

Ultra-wide band (UWB) technology could be a good candidate for an accurate localization of smart devices and sensors on- and in- the body. UWB can be also used successfully to enhance the accuracy of other positioning technologies. Diversity navigation employing multiple sensing technologies can overcome the limitation of individual technologies, in particular in harsh environments [4].

On the other hand, Dead Reckoning (DR) techniques enable localization systems to rely more on body worn sensors than on external infrastructures such as the GPS system [5]: in the framework of the HBC systems, the DR devices could resort to the Micro Electro-Mechanical Systems (MEMS) [6] technology which made low-cost sensors available on the market. Therefore, HBC systems can benefit from the massive research activities which have been recently focused on the definition of a more effective recognition of movement in the DR applications [7] in order to obtain a more precise position fix.

2.3 WBAN

Nowadays the digitalization of human perceptions and sensations, so that this new very personal information can be shared is a frontier of ICT. Imagine the future: every human beings carrying one or more sensors that sense or reveal a very personal information, when this information is created by the body, such as tasting a delicious food, touching a new irregular surface, looking at the preferred color or watching something horrible, could be only an infinitesimal part of the perception and sensations that the body generates in our everyday life.

In order to digitalize this new kind of information, a wearable device is required. The device will be capable of revealing the information, transforming it into a digital content and sending it through a communication channel. Thus, the concept is that the humans have to carry a so-called body area network (BAN), which detects and then transmits the information. Due to the mobility issue, the information is usually sent by a wireless link. Moving personal health data has a very similar security issues of HBC data, since both are very private and must not be modified or accessed by not-authorized personnel.

As an example in the healthcare context, the evolution of WBAN will go towards the human bond communications.

The WBAN has emerged as a new technology for e-healthcare that allows the data of a patient's vital parameters and movements to be collected by small wearable or implantable sensors and communicated using wireless links. WBAN technology has great potential in improving healthcare quality, and thus has found a wide range of applications from ubiquitous health monitoring and computer assisted rehabilitation to emergency medical response systems (Fig. 2).

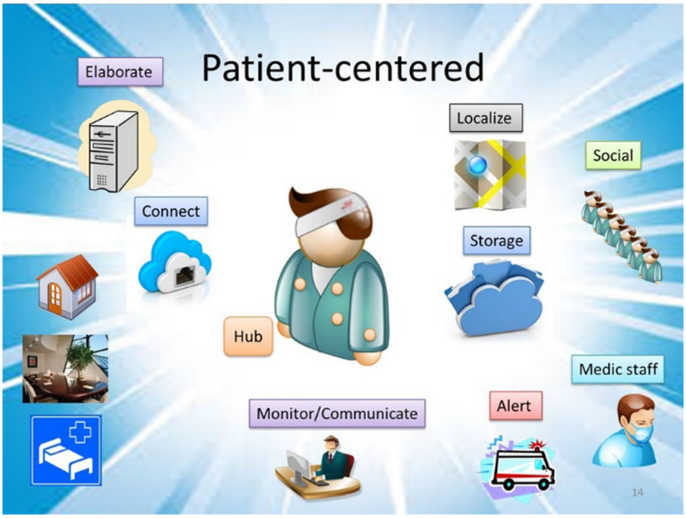

Fig. 2 Wireless distributed e-health data

The benefits of WBAN are many, but mainly this one: instead of being measured face-to-face, patients' health-related parameters can be monitored remotely, continuously, and in real time, and then processed and transferred to medical databases. This medical information can be then shared and accessed by various authorized users such as healthcare staff, care-givers, researchers, government agencies and insurance companies.

Since the person-related data stored in the WBAN plays a critical role in medical diagnosis and treatment, it is essential to ensure the security of this data. Failure to obtain authentic and correct medical data will possibly prevent a patient from being treated effectively, or even lead to wrong treatments. Therefore, it is extremely important to protect patient-related data against malicious modification and, at the same time, to ensure the reliability and dependability of the data. Protection issue ranges from data stored inside the on/in-body device to the transmission of data to the off-body network (Fig. 3).

To design data security and privacy mechanisms for WBANs means to find balances between security, efficiency and usability. Stringent resource constraints on WBAN devices, e.g. the sensor nodes, basically require the security mechanisms to be as light-weight as possible. As expected, the security design to let HBC become real is a hard task, since security mechanisms must be at the same time:

- robust but lightweight,
- low latency but dependable,
- unbreakable but simple.

In the HBC vision, the data are not health-related but still has the same importance, since they represent the senses and sensations of an individual. This kind of data can lead to a superior profile of a subject, much more than today algorithms exploiting the "Internet life" of an individual. Such superior profiles are pure gold for companies that today spend millions of dollars to buy customers profiles from big digital industries, such as Google, Facebook, etc.

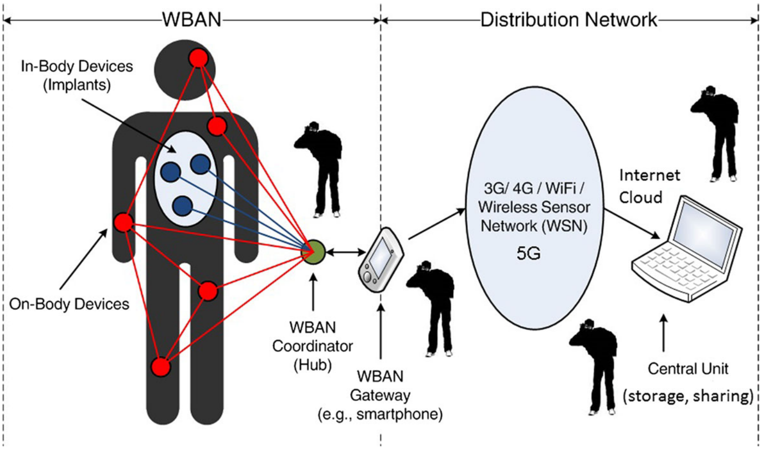

Fig. 3 On-body and off-body wireless networks with possible eavesdropping points

3 Security and Resilience

The HBC will happen to operate in open-access environments, which means that they can also accommodates attackers. The open wireless channel makes the data prone to being eavesdropped, modified as well as jammed. Together with threats to stored data, other threats can come from the device compromise as well as from the network dynamic.

The sensor nodes worn by a HBC user are subjected to compromise, since they can be usually easily taken and opened or tampered. If data is directly encrypted and stored in a node along with its encryption key, the compromise of this node will lead to the disclosure of the data. In addition, local servers may not be trustworthy, since malicious people can either attack it remotely from Internet, or simply go physically to the room where a HBC user is and wait for the chance to compromise the local server.

In addition, the HBC network dynamic is highly time-variant, i.e. nodes may join or leave the network frequently. Nodes may leave out due to battery low or due to a malicious attack. Other types of attacks may easily replace legitimate nodes with faked sensors and take away legitimate nodes with data inside. The personal-related data, if not well kept in more than one node, could be lost easily due to the network dynamics. Moreover, false data could be injected or treated as legitimate due to lack of authentication.

All these possible threats lead to stringent requirements when building the security of HBC.

3.1 Security Requirements for HBC

Given the above mentioned threats, in this paragraph the requirements for security in HBC are reported. The requirements are divided into two main groups: data storage and data access.

3.1.1 Security Requirements for Distributed Data Storage

Security requirements for distributed personal-data storage mainly deal with:

- *Confidentiality* In order to protect person-related data during storage periods, the data needs to always be kept confidential at a node or local server. Data confidentiality should be resilient to device compromise attacks, i.e. the attacker does not gain any information or little if it steals/compromises a node.
- *Integrity* Data integrity must be protected all the time. In particular, end users must be made capable to detect modifications of the data. Potential malicious modifications or unauthorized accesses must be revealed during the storage period and eventually alert the end user.
- *Dependability* Dependability is another critical concern in HBC. In order to tackle the threats caused by network dynamics, fault tolerance is required, which means that patient-related data must be readily retrievable even under node failure or malicious modifications.

3.1.2 Security Requirements for Distributed Access to Personal Data

Data access security basically deals with:

- *Data access control* Access control needs to be enforced for HBC-related data so that private information cannot be retrieved by unauthorized parties. A fine-grained access policy must be defined, i.e. different access privileges for different users. Depending on the privilege, different user role and different part of data can be accessed.
- *Scalability* HBC is going to be a spread-over technology, which means millions of users on a time. Thus, the distributed access control mechanism should be scalable with the number of users in order to low management overhead of the access policies as well as low the computation and storage overhead.
- *Flexibility* A basic requirement is that the individual should have the power to select which is the access point to connect for transmitting the personal data.
- *Accountability* When a user of the HBC abuses its own privilege to carry out unauthorized actions on personal-related data, it should be identified and informed about the prosecution of the abuse.
- *Revocability* The privileges of HBC users/nodes should be revoked if they are identified as compromised or malicious.
- *Non-repudiation* The origin of personal-related data cannot be denied by the source that generated it.

3.2 New Threats from Smarter Radio Systems

As known, the cognitive paradigm of communication has been thought in order to use the scarcity of the spectrum with high efficiency. On the other hand, adding intelligence (“cognitivity”) to the devices means more opportunities for malicious users [8]. The logic of primary and secondary users/networks can be embarrassed by a selfish user. For example, a primary selfish user can push energy in a channel in order to let it appear as occupied for secondary users. Or anyway, if the spectrum sensing result is modified maliciously, normal network activities will be disabled and even the whole network traffic may be broken down [9].

HBC will require abundant use of the spectrum resource. Thus, cognitive radio approach will surely be a candidate to enable HBC in future wireless networks. Security issues are extremely important to be investigated and solved together with the development of a new communication service and system such as HBC. With HBC not only the classical personal data but also very personal sensations of an individual are delivered wirelessly all over the world.

3.3 Possible Solutions

Trying to image which solutions can be added to a communication system in order to support HBC services securely is a very hard task. Basically, the future HBC system will require to add two main features to the classical network security solutions: biometric encryption and physical-layer security. The former to protect the data from unauthorized access and reading of very personal data, the latter for securing the physical link where this information flows.

3.3.1 Biometric Encryption

Biometrics is the science of establishing the identity of an individual based on the physical, chemical or behavioral attributes of the person [10]. Mainly the concept is that the user is not authenticated/identified by something that he/she knows (password, etc.) or carries (sim cards, chips, etc.), but by some biological attribute which is unique for each individual.

The sensation transductor can give an added value to biometrics. Not only biological attributes are unique in a human being (retina, fingerprint, DNA, etc.), but also sensations, or, in particular, answers to stimuli. HBC systems can let the biometrics becomes "sensemetrics". Answer to a particular stimulus can be used to identify and authenticate the user. For example, the system can send to the user a known food taste and then evaluate the sensation answer.

Sensations of the user can also be used to encrypt the personal data of the user during the "journey in the Net". Sensations can be translated into a private key which encrypts the data. Only the individual that can reproduce that sensation of answer to a specific stimulus can decrypt the data and read it.

3.3.2 Physical-Layer Security

Most commonly used security methods rely on cryptographic techniques, either asymmetric (based on public and private keys) or symmetric (based on a shared secret not known by others), which are located at the upper layers of a wireless network. Encryption does not protect from the undesired demodulation of the information by eavesdroppers, but only from the interpretation of the data as meaningful words. The cryptographic protocols base their security on the fact that, statistically, the amount of time for performing a decrypting analysis is enormous. The time to break a codeword is related to the computational power of the attacker, i.e. cryptography intrinsically assumes that the eavesdropper has a limited amount of computational capability. Recent efforts of academia and industries to power up the amount of operations per second of the digital processors make this assumption weaker and weaker. Physical layer security does not make any assumption on the computational power of the attackers [11].

Security at physical layer is historically mainly intended as the use of a spread spectrum techniques (frequency hopping, direct sequence coding, etc.) in order to avoid the eavesdropping. Eavesdropping at the physical layer refers to hiding the mere existence of a node or the fact that communication was even taking place from an adversary. Moreover, scrambling the information data with a code does not assure a totally secure channel, but just a long decryption time activity before getting the code by an unwanted listener, i.e. the security is moved on the quantity of resources (hardware, time, etc.) that the unwanted listener must have in order to get the information.

4 Potential Application Contexts and Main Challenges

4.1 HBC Applications

HBC can be adopted in multiple application contexts. Some of the most significant ones are detailed in the following:

- Health and Wellness applications
- Therapies against emotional cognitive limitations
- "Workplace Hazards" applications
- Cultural and documentation applications

4.1.1 HBC for Health and Wellness applications

Remote experiences have been adopted for improving the health conditions of people and dealing with chronical diseases [12, 13]. Wellness multi-sensorial applications for smartphones and wearable devices are new opportunities and are literally exploding in popularity [14]. All the key device manufacturers propose sensor extensions for wellness and healthcare (Apple iWatch, Android Wear, Samsung Galaxy Gear to cite the most popular), they are based on sophisticated sensor technologies coupled with a near smart phone through low-power wireless communications. A natural extension to this concept is the exploitation of two-way sensors/transducers offered by HBC paradigm.

4.1.2 HBC for Therapies Against Emotional Cognitive Limitations

The complete multisensorial experience that has been described in the previous application could be also used also in the definition of suitable therapies for dealing with emotional and cognitive limitations, especially for children: the emulation of a full reality in a controlled environment could help specialists to understand real dynamics of behaviour and to define proper cure strategies

4.1.3 HBC for "Workplace Hazards" Applications

HBC can also have a role in emergency situations. Consider, as an example, a fire rescue operation. The first responders operate in critical environments where fast decisions have to be taken for saving people lives. In this context an external help could be vital, but conventional communications are not effective due to lack of perceived elements of remote assistants. Local operation command center is usually connected with two-way radios and the exchange of information with the responders are limited to reports and situation summary. HBC could fill the perception gap by providing the remote helper with an augmented set of natural senses as perceived by the responder, as shown in Fig. 4. Smell of burning substances, directional heat, floor vibrations, could increase the contextual awareness of remote assistants, helping the responder to take correct decisions.

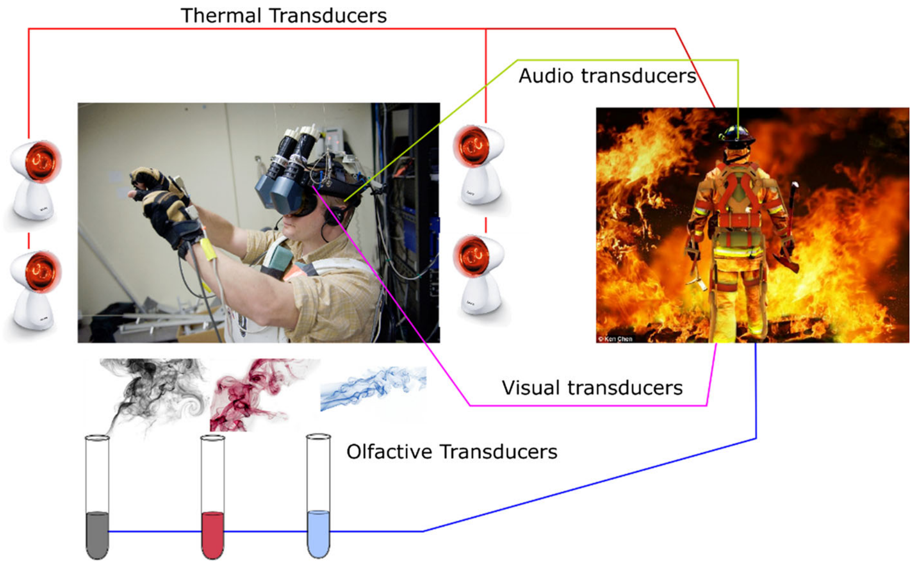

Fig. 4 HBC application example

4.1.4 HBC for Cultural and Documentation Applications

As for the culture and entertainment fields, the possibility to recreate a full sensorial experience will allow to define site specific contemporary art works and to design more effective perception of real life conditions in some didactical museums.

4.2 Open Key Issues for HBC

Several communication challenges however need to be solved for the definition of the previous HBC applications. The key issues for the adoption of HBC on wearable devices can be summarized in:

- Energy efficiency
- EMC (Electromagnetic Compatibility) issues
- Fluid Reconfigurability and Resiliency

4.2.1 Energy Efficiency

Battery exhaustion is the most annoying drawback of smart devices. Waiting for new energy storage technologies to become available, a great improvement of availability for these sensors/transducers can be obtained through power efficient design of devices. Due to their inherent characteristics, the power budget is sensibly unbalanced toward the radio component, rather than the sensor signal processing. Improvements on this side will result in sensible increases of service availability. ETSI DTR/Smart-BAN working group proposes standard solutions for wearable networks (WBAN), exploiting the peculiar characteristics of high efficient wireless technologies like Ultra-Wideband Communications.

4.2.2 EMC Issues

In HBC applications where the detected biological signal is weak, RF power emitted by near radio devices can degrade the service. In these circumstances, communication technologies based on different approaches can be the solution. Visible Light Communication is gaining attention from scientific and market communities for some peculiarities in this sense. Visible light frequencies are completely out-of-band with respect to sensor/transducers signals. The emission and detection of VLC waveforms can be performed at high rates with efficient energy using high speed LEDs and photodetectors. The perceived biological compatibility of visible light is higher than radio signal for (under) skin-wearable devices.

4.2.3 Fluid Reconfigurability and Resiliency

The IoT (Internet of Things) paradigm will surely play a role on the new HBC concept for wellness and health. The HBC wearable devices can benefit from the most recent advances on Cognitive Radio and Network technologies, providing a seamless automatic network (re)-configurability also in reaction to availability events due to energy shortages. The missing HBC node must not impact on the remaining network performance, and this is the result of the integration of different Cognitive technologies. The exploding number of sensor/transducers will also benefit from IPv6 whose addressing space avoids complex network address translations form the LL and Networks layers.

5 Conclusions

The paper envisions the steps to be taken in order to make human bond communications a visionary building block of a future telecommunication ecosystem. HBC will enhance the experience of the nowadays mobile users by adding the five senses experience to the digital information flow. Enabling such an innovative technology is a hard technological challenge. This paper summarizes the requirements and the challenges to enable HBC, starting from the 5G boosting and including localization and security issues. For the sake of concreteness, potential applications of HBC have been outlined such as health/wellness application and work safety in hazardous environments.

References

1. Del Re, E., Morosi, S., Ronga, L. S., Jayousi, S., & Martinelli, A. (2015). Flexible heterogeneous satellite-based architecture for enhanced quality of life applications. *IEEE Communications Magazine, 53*(5), 186–193. doi:10.1109/MCOM.2015.7105659.
2. Prasad, R. (2015). Human bond communication. *Wireless Personal Communications,*. doi:10.1007/s11277-015-2994-x.
3. Soldani, D., Pentikousis, K., Tafazolli, R., & Franceschini, D. (2014). 5G networks: End-to-end architecture and infrastructure. *IEEE Communications Magazine, 52*(11), 62–64.
4. Conti, A., Dardari, D., Guerra, M., Mucchi, L., & Win, M. Z. (2014). Experimental characterization of diversity navigation. *IEEE Systems Journal, 8*(1), 115–124.
5. Morosi, S., Jayousi, S., Falletti, E., & Araniti, G. (2013). Cooperative strategies in satellite assisted emergency services. *International Journal of Satellite Communications and Networking, 31*(3), 141–156. doi:10.1002/sat.1028.

6. Yazdi, N., Ayazi, F., & Najafi, K. (1998). Micromachined inertial sensors. *Proceedings of the IEEE, 86*, 16401659.
7. Martinelli, A., Morosi, S., & Del Re, E. (2015). Daily movement recognition for dead reckoning applications. *Proceedings of IPIN*, 1–8. doi:10.1109/IPIN.2015.7346769.
8. Mucchi, L., Carpini, A. (2014) Aggregate interference in ISM band: WBANs need cognitivity? In *2014 9th international conference on cognitive radio oriented wireless networks and communications (CROWNCOM)*, pp 247–253.
9. Mucchi, L., Ronga, L. S., & Del Re, E. (2011). Physical layer cryptography and cognitive networks. *Wireless Personal Communications, 58*(1), 95–109.
10. Jain, A. K., Flynn, P., & Ross, A. A. (2007). *Handbook of biometrics*. Berlin: Springer.
11. Mucchi, L., Ronga, L. S., Cipriani, L. (2008). A new modulation for intrinsically secure radio channel in wireless systems. Special issue "information security and data protection in future generation communication and networking", *Wireless Personal Communications 51*(1): 67–80, October 2009.
12. Pierucci, L., & Del Re, E. (2000). An interactive multimedia satellite telemedicine service. *IEEE Multimedia*, *7*(2), 76–83. doi:10.1109/93.848435.
13. Ronga, L. S., Jayousi, S., Del Re, E., Colitta, L., Iannone, G., Scorpiniti, A., Aragno, C., & Neja, C.P. (2012) . TESHEALTH: An integrated satellite/terrestrial system for e-health services. *IEEE International Conference on Communications (ICC),* 2890–3286. doi:10.1109/ICC.2012.6363952.
14. Rodgers, M. M., Pai, V. M., & Conroy, R. S. (2015). Recent advances in wearable sensors for health monitoring. *IEEE Sensors Journal, 15*(6), 3119–3126.

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