Modelling Dynamic Body-to-Body Channels in Outdoor Environments

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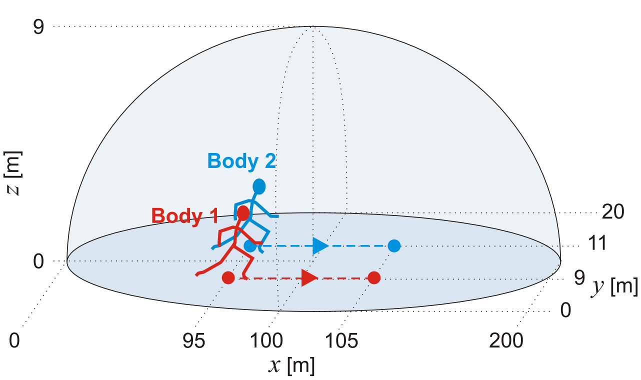
I. EXTENDED ABSTRACT

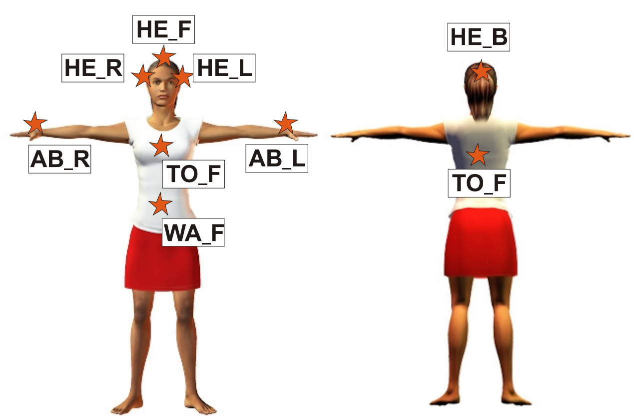
Wireless Body Area Networks (BANs) refer to body centric wireless communications, [1], [2], where one or more of the communication devices are attached to the human body. When communications take place between wearable devices on two independently moving bodies, the body-to-body channel is considered, [3]. In this case, the antennas on both sides of the radio link are influenced by the presence of the body. The goal of this paper is to address the development of a flexible method to model radio channels in body-to-body communications.

The model can be applied to any type of antenna, however, the radiation pattern of the antenna has to be previously modelled on the static body (e.g., voxel model) using full wave simulations, [4]. This ensures that the coupling of the body, which has an impact on the radiation pattern of antenna, is included. As the proposed model for body dynamics is based on motion capture analysis, [5], any type of body movement can be considered (e.g., run). The environment consists of clusters of scatterers, and the Geometrically Based Statistical Channel model adapted to the BANs is used, [6], to calculate Multi-Path Components (MPCs).

The practical scenario of 2 bodies running in a street in an urban area (i.e., micro-cell) has been taken as a study case, Fig. 1. A patch antenna, [7], operating in the 2.45 GHz Industrial, Scientific, and Medical (ISM) band is used. There are several typical placements of antennas in BANs, the following locations on both bodies being analysed: TO_F and TO_B (front and back side of the Chest); WA_F (front side of the Waist); HE_F, HE_B, HE_L and HE_R (front, back, left and right side of the Head); AB_L and AB_R (left and right side of the Arm). This results in 81 possible body-to-body links. In order to model the street environment, a set of 10 clusters, of 3 scatterers each, has a uniform distribution in the half space of an ellipsoid. Two bodies are running in parallel on a straight line, in the middle of the street, with a 2 m separation between body centres. The running speed was set to 14.4 km/h. In order to obtain statistical parameters, each dynamic scenario has been repeated 30 times (for a random distribution of scatterers).



(a) street environment



(b) antenna placement

Fig. 1. Scenario (dimensions not to scale).

The path loss strongly depends on the orientation of the antennas on both bodies, and the following cases can be considered:

- Co-Directed: when the maximum gain of one antenna is directed towards the other body,
- Opposite-Directed: when the maximum gain of one antenna is directed in the opposite direction to the other body,
- Cross-Directed: when the maximum gain of one antenna is directed in the orthogonal direction to the other body.

Therefore, 6 cases can be distinguished: Co-Co-Directed (CCD), Co-Cross-Directed (CXD), Co-Opposite-Directed (COD), Cross-Cross-Directed (XXD), Cross-Opposite-Directed (XOD), and Opposite-Opposite-Directed (OOD). The average path loss between antennas coming from different classes is presented in Fig. 2.

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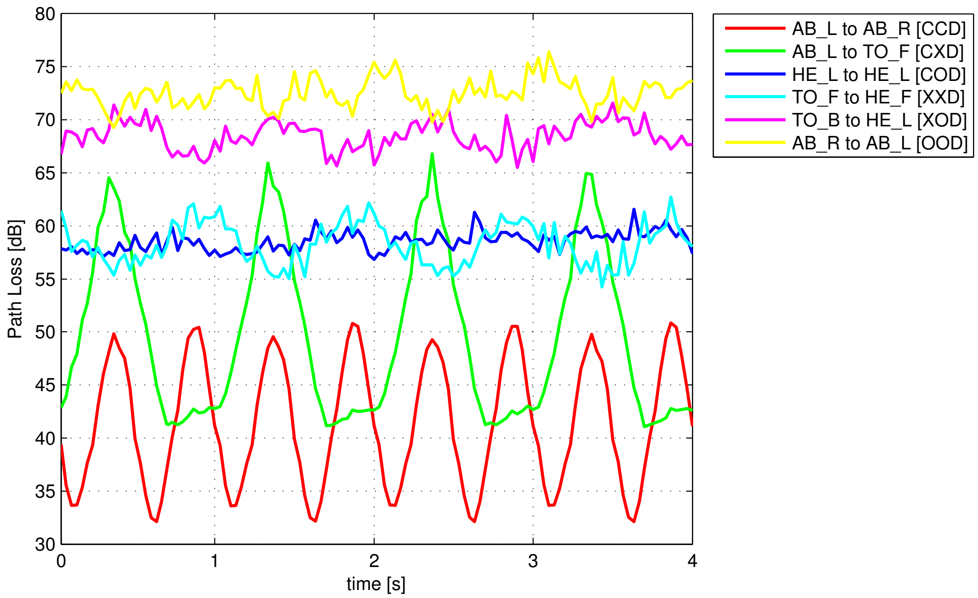

Fig. 2. Path loss for different classes.

Due to body dynamics, the average path loss varies a lot, especially when antennas are placed on the most dynamic body locations (i.e., AB_L or AB_R). In this case, the difference in the average path loss during one run period (i.e., 2.5 m) can reach 25 dB. The average and the standard deviation (STD) of the average path loss for the different classes is presented in Table I.

TABLE I. THE AVERAGE AND STANDARD DEVIATION OF THE AVERAGE PATH LOSS.

		CCD	CXD	COD	XXD	XOD	OOD
path loss [dB]	average of the average	36.9	48.1	57.7	59.1	67.3	74.9
	STD of the average	3.5	1.4	2.6	2.1	2.0	2.5

As expected, for the CCD links, the average of the average path loss is the lowest, equal to 36.9 dB. On the other hand, for the OOD links, the average of the average path loss is the highest, equal to 74.9 dB. In this case, the antennas are in NLoS and propagation is mainly due to double bounced MPCs. It is worthwhile to notice that for the LoS free space propagation (when patch antennas are constantly oriented to each other with the maximum gains, and body dynamics are not considered), the calculated path loss is 33.6 dB. In general, the STD of the average path loss is below 3.5 dB, which means that the average path loss is similar for different links coming from the same class.

II. CONCLUSIONS

In this paper, a radio channel model for body-to-body communications in a street environment is introduced, and a statistical analysis of path loss is performed for links that can be split into 6 classes, depending on the antennas orientations. As expected, the best connectivity is obtained for Co-Co-Directed antennas, with the average of the average path loss being 36.9 dB. Body dynamics has a significant influence on path loss, and the difference in the average path loss during one run period can reach 25 dB.

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