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Human Mobility Patterns at the Smallest Scales

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Abstract. We present a study on human mobility at small spatial scales. Differently from large scale mobility, recently studied through dollar-bill tracking and mobile phone data sets within one big country or continent, we report Brownian features of human mobility at smaller scales. In particular, the scaling exponents found at the smallest scales is typically close to one-half, differently from the larger values for the exponent characterizing mobility at larger scales. We carefully analyze 12-month data of the Eduroam database within the Portuguese university of Minho. A full procedure is introduced with the aim of properly characterizing the human mobility within the network of access points composing the wireless system of the university. In particular, measures of flux are introduced for estimating a distance between access points. This distance is typically non-Euclidean, since the spatial constraints at such small scales distort the continuum space on which human mobility occurs. Since two different exponents are found depending on the scale human motion takes place, we raise the question at which scale the transition from Brownian to non-Brownian motion takes place. In this context, we discuss how the numerical approach can be extended to larger scales, using the full Eduroam in Europe and in Asia, for uncovering the transition between both dynamical regimes.

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Key words: Networks, data analysis, human mobility.

1 Motivation and scope

Understanding human motion from small scales, such as buildings and streets up to larger ones comprising cities, countries and continents, has been proven to be important for a variety of application areas such as spread of diseases, opinion dynamics [1, 2],

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and any other phenomena occurring on social networks [3], as well as in optimization of telecommunication networks, urban planning or tourism management. With these aims, several groups have been modeling human motion during the past few years [4–7].

At middle and larger scales highly significant contributions for understanding human mobility have been made. Brockmann and his team [5], for example, have shown that human traveling distances within U.S.A. decay as a power-law. On the other hand, Gonzalez and co-workers [4] have shown that there is a high degree of temporal and spatial regularities with a single probability distribution for returning to previous locations. However a study occurring at lower scales, namely within one single building or a small set of buildings still lacks to be addressed. One of the reasons for this lays in the nature of available data. For instance, Brockmann and his team [5] used data obtained from an online bill tracker system where registered users report the observation of marked US dollars bills around the United States, and a data set representing the position of travel bugs in GeoCaching systems. Though reasonable, these data sets however do not represent human motion directly. González and co-workers [4] proposed a way for tracking human motion, using a data set containing positioning records of around 10^5 users of a cellular network collected over a period of six months. Since mobile phones are personal devices, the trajectory of a mobile phone is highly correlated to that of his owner, turning to be a much better proxy to observe the trajectories of humans than bills or other non-personal items.

However, two drawbacks should be stressed in the data sets used so far. First, in both cases the data records correspond to position data collected only when a person initiates/receives a phone call or a SMS message, or when he or she declares online the dollar bill. Second, there is the problem of spatial resolution. For example, for cell ID, the data cannot be used to validate the proposed models at short scales, since the coverage area of mobile network cells extends to several kilometers in rural areas.

In this paper we analyze a large data set of Eduroam networks at Portuguese Universities (see Fig. 1), with the aim of addressing the problem of human motion at the smallest scales, i.e. within one or a few buildings. Our study follows from previous work [9–11]. The data set comprises one year of collected information with a sample frequency of one second, a time step that enables to assume the data as continuous monitoring of human mobility, and with a higher spatial resolution than mobile phone calls data sets which enables the motion of human dynamics at its smallest scale. We will show that the statistical features of human mobility at the smallest scales is much closer to the random-walk model than the results obtained for studies at larger scales. Still, the corresponding exponents we find in this study indicate a super-diffusive regime which we address in the end for discussing possible ways of using such statistical information to optimize Eduroam networks when establishing the location of the access points.

The complex network framework has been applied frequently to address social and environmental problems [14–18]. For recent reviews see [12, 13]. While using the same framework, we introduce here a novel procedure for extracting the network on which persons move at small scales (university buildings), directly from empirical data.