Poster Abstract: An Empirical Study of WiFi-based Radio Tomographic Imaging

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ABSTRACT

Radio Tomographic Imaging (RTI) enables device free localization of physical objects by using signal attenuation in wireless networks. In this paper, we explore how existing RTI methods can be used in WiFi networks to do tomographic imaging. Moreover we analyze and evaluate the properties that affect the accuracy of WiFi tomographic imaging process.

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1 INTRODUCTION

Various real-world scenarios raise the need of localizing humans within enclosed environments. Disasters such as building collapses, building fires and intruder detection are to name a few. Such scenarios require the use of a passive and non-intrusive method to detect the presence and movements of humans effectively. Radio Tomographic Imaging (RTI) is such a technique that creates a cross-sectional image of an area by using radio signal attenuation due to the presence of objects [3]. RTI is performed by placing multiple radio transceivers around a target area in a way that the radio links interconnecting the transceivers create a grid over the target area. The links which go through objects within the area faces a higher attenuation compared to the other links. This attenuation is measured and used for the image construction. Unlike fingerprinting-based method which requires comparison of measurements with a database of collected values [2, 4], RTI follows the model-based method that does not rely on a training measurement database.

Most of the RTI researches on the 2.4 GHz frequency have used transceivers based on IEEE 802.15.4. Researches which were on WiFi-based RTI is very limited [1]. Due to the heavy use of WiFi connected devices, these WiFi networks have become abundant and at a given place, multiple WiFi networks served by multiple access points can exist. Patwari et al [1] have evaluated the accuracy of detecting moving humans/objects using both IEEE 802.15.4 and IEEE 802.11 transceivers. According to that ZigBee transceivers have outperformed WiFi in indoor environments, but in an environment where there is minimum scattering this has shown quite opposite results. This indicates that WiFi-based RTI is better suited for outdoor environments than the popular IEEE 802.15.4 based RTI.

2 MODEL

The objective of an RTI system is to derive a cross sectional image vector of an area, based on the power attenuation of the radio signals. Since the attenuations considered are due to the physical objects within the radio network grid, shadowing based image vector construction is the mostly used method in the previous works [3, 5]. In this method, each radio link is considered as an ellipse where the focus points are located at the sender and receiver nodes [3, 5]. Any physical object which lays within the region of such an ellipse is considered to be obstructing the corresponding radio link, hence contributing to the signal attenuation. For image construction the final solution with Tikhonov regularization[3] applied can be written as:

$$\hat{x} = (W^T W + \alpha({D_X}^T D_X + {D_Y}^T D_Y)^{-1} W^T y) \qquad (1)$$

where y is the vector of all link difference RSS measurements, $\hat{x}$ is the attenuation image that is to be estimated, W is the weight matrix, D_X and D_Y are the different operators for the horizontal and vertical directions[3].

3 EXPERIMENTS AND RESULTS

In this research we have selected an inexpensive WiFi-enabled module called *ESP8266* as the transceiver nodes. The network consists of 12 such nodes placed around a 6.4m x 6.4m area as shown in the Figure 1(a). This choice of the node placement follows the previous work in [3] as it is the most effective arrangement. Each node is in the transceiver mode with the transmission power set to 20.5 dB. The Figure 1(b) shows the setup of the experiment where a human is standing in the middle of the network without moving for approximately 6 minutes. The results of tracking the human against the true location is illustrated in Figure 2.

3.1 Empirically finding the ellipse width

The choice of ellipse width removes the voxels that do not contain useful information and takes voxels near LOS that contain information for a particular link. It is then normalized by the link length. The Figures 2(c) and 2(d) shows how does having different values

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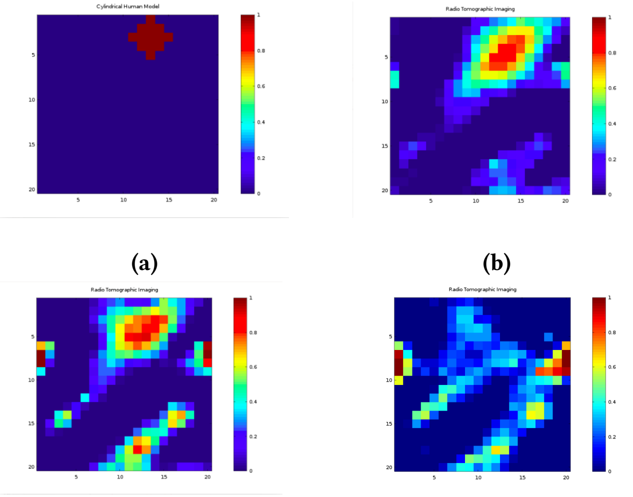
(a) (b)

Figure 1: (a) illustrates the topology of the RTI network while (b) illustrate the physical setup in an open field.



(a) (b) (c) (d)

Figure 2: (a) illustrates a true location of a human in the arena while (b), (c) and (d) illustrates how it is visible in the RTI window with eclipse widths 0.1 and 0.05.

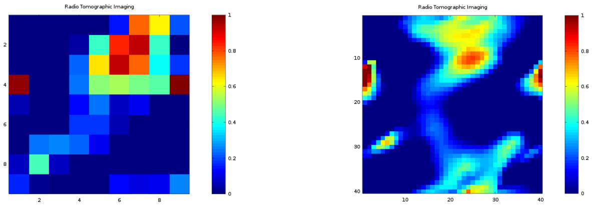
to ellipse width affect the correct localization shown in Figure 2(a). The regularization parameter is set to 5, in both ellipse width testing and voxel size testing. This choice of regularization parameter was also tested empirically.

3.2 Empirically finding the voxel size

The locations were empirically tested for different voxel sizes. The pixel dimensions are the same as the chosen voxel size. In Figures 3(a) and 3(b), the same location in Figure 2 is compared with two other voxel sizes which illustrate the effect of voxel size on accuracy of location. The width of the ellipse is 0.2 feet.

3.3 Error Calculation

A true attenuation image is the cylindrical model representation of human [3]. For RTI, brightest blob in RTI attenuation image is taken. It is the euclidean distance from true cylindrical center to the brightest pixel in the RTI image blob center that is taken as the error calculation method.



(a) (b)

Figure 3: RTI windows with voxels (a) 8x8 and (b) 40x40.

In Figure 4 the error with voxel size and chosen ellipse widths is plotted. We observe that for this particular network, on average the voxel size 9x9 gives a low error rate for any width of ellipse chosen. Also for all three voxel sizes, the ellipse widths 0.1 and 0.2 show a low error rate. Therefore, empirically we can derive a suitable voxel size and ellipse width in this way.

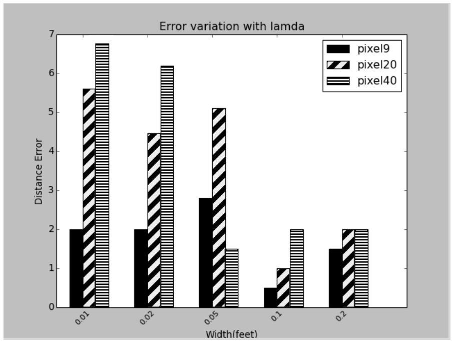


Figure 4: Error variation with voxels and widths.

4 CONCLUSION

WiFi-based RTI has a clear advantage over IEEE 802.15.1 transceivers in the outdoor environment. However, WiFi-based RTI can be affected by the noise of existing WiFi networks which can be studied in future research. In this research we investigated the accuracy of the image reconstruction with the voxel size and ellipse width in WiFi tomography.

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