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A Review on Autonomous Relay For Millimeter Wave Wireless Communications

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Abstract. Millimeter-wave wireless communication is an uprising technology. Millimeter-wave has large bandwidth and short wavelength. Eventhough it is advantageous, it gets easily blocked by obstacles. As a result, effective communication does not take place. Relays are used widely to solve this problem. Unmanned Autonomous Vehicles (UAV), such as drones, allows the mobile relays in real applications. It is difficult for relay to find its position quickly and accurately. Here, a method AutoRelay specialized for mmwave communication have been reviewed. In AutoRelay, the link qualities of mmwave beams are sampled while moving. Based on real-time sampling, UAV adjusts its path to reach the optimal location by using compressive sensing theory which increases accuracy and saves time.

1. Introduction

Mm wave communication operates at 3 to 300 GHz and its available bandwidth is upto multiple GHz[2]. It provides multi gigabit transmittability for wireless information shower[3]. Because of its short wavelength, multiple antennas can be consolidated in a tiny space. But the communication range of mm wave is shorter than existing wireless technologies as it attenuates more severely in air. Also, it is easily blocked by obstacles[4]. It does not have sufficient power to go through obstacles[5].

To compensate these disadvantages, relays are essential. In simple terms, relays are interconnection between source and destination. they receive and re transmit signals. They do not need wired connections to the network. With the development of Unmanned Aerial Vehicles (UAVs), mobile relays have become possible in real applications.

It is challenging for a UAV to find its optimal location accurately and quickly. Measuring the link qualities between transmitter and receiver in all possible space and selecting the optimal one is an accurate method. But it takes long time.

Thus, an autonomous relay (AutoRelay) measures real time link qualities while moving. UAV automatically adjusts its path to approach the optimal relay location quickly by taking advantage of compressive sensing and online estimation of link qualities in the whole candidate space.

AutoRelay has two advantages:

- i) AutoRelay can estimate the optimal location accurately by combining the mmWave model, real-time sampling, and compressive sensing theory.
- ii) AutoRelay can quickly arrive at the relay location by making use of online update and continual approaching mechanism.

2. AutoRelay

Relays are common solutions to maintain the connection between disconnected transmitter and receiver. At the begining, works were concentrated on static relays [6]. Static relays can work for a long term because of its stable power supply. However, it required a large amount of redundant relays to increase the connectivity of such networks. Then, the cooperative strategies and capacity theorems were analyzed[7]. Signal alignment along with its degrees of freedom for MIMO relay channels with clustered pairwise exchange was also studied[8]. With the development of UAVs, mobile relays took charge[9]. The performance of UAV based wireless relay communications were analyzed[10]. Mobile relays were used to offer high quality LTE services[11]. But these relays does not fit the relay problem to ensure the quick search of optimal location.

2.1. System Model

The basic system includes one transmitter (Tx) and one receiver (Rx). The transmitter transmits signal to the Receiver, but due to its shorter wavelength, it is blocked by obstacles.

2.1.1. Space Model A 3D space is set up by taking the mmWave transmitter as the origin o with coordinates (0, 0, 0) and the mmWave receiver as the point c with coordinates (n_1, n_2, n_3). The optimal relay location is somewhere in this 3D space.

A 3D matrix Q is created to represent the link qualities where (n_1, n_2, n_3) are the scales of the three dimensions. The space is split into (n_1, n_2, n_3) small cubes and link quality in one certain cube is assumed to be same. The value of each cube Q (i, j, k) of the matrix denotes the link quality of mmWave transmission if the relay is set in (i, j, k).

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2.1.2. Link Quality Model In order to measure the link quality for each location,a model is provided for mmWave transmission by considering the large-scale path loss, the shadowing loss and the non-shadowing loss.

Both the source side and the destination side should be considered for link quality evaluation. The obvious method to describe the link quality is the received transmission quality from certain points. The transmission quality at the destination point received from the relay point is equivalent to that at the relay point received from the destination point. So, we consider the receiving qualities at the relay point from both the source point and the destination point as factors in representation of link quality metrics.

Let S_o be the sending quality at the origin o, S_c be the sending quality at the receiver c, R_o(i, j, k) be the receiving quality from point o at point (i, j, k) and R_c(i, j, k) be the receiving quality from point c at point (i, j, k).

The link quality Q (i, j, k) is described as the product of the receiving qualities R_o (i, j, k) at point (i, j, k) from origin point o and R_c (i, j, k) at point (i, j, k) from receiver c, according to data transmission model. The product of these two values is taken as the metric to achieve the optimal transmission quality for the relay.

2.2. Mobile Relay System

The mobile relay aims to find the optimal location with the best link quality. A strategy of path choosing is developed for the relay and a method to update the quality matrix Q in an online manner. The mobile relay uses the data transmission model and flies along the path according to the strategy in the space with the initialization of the quality matrix Q.

The space model is based on the transmitter o (0, 0, 0) and the receiver c (n_1, n_2, n_3). A strategy is designed for the relay to find the optimal point $P(P_x, P_y, P_z)$ so that the link quality $Q(Q_x, Q_y, Q_z)$ is maximized, given the start point of mobile relay $S(S_x, S_y, S_z)$ and the initial quality matrix Q. Because noise, multi-path, dynamics, and other factors cannot be perfectly modeled, the link quality calculated by the theoretical model contains errors. Hence, the online measurement and updates are necessary to correct the theoretical results. However, measuring the link quality at all locations of candidate space costs too much time. So the AutoRelay only samples at a few locations and estimates other locations using compressive sensing.

2.2.1. Optimal Location Finding It is assumed that the points o, c, s are known initially. These points are obtained by the mobile using the camera to observe the location of the transmitter and the receiver. Then the corresponding 3D space is setup by taking the location of transmitter as the origin o (0, 0, 0) and the location of the receiver as $c(n_1, n_2, n_3)$. Also, the mobile relay start is setup at the initial point $S(S_x, Sy, S_z)$.

Then, the initial values for the 3D quality matrix Q are set. The quality matrix is initialized taking only the large-scale path loss into account, as shadowing and non-shadowing losses are relatively less as compared to large scale path loss. Any form of the distortion on the transmission link quality is corrected in the matrix update using the sample real data.As a result, the initialization does not consider the distortion or the attenuation. Optimal location is selected and the relay flies towards that location.

Samples are taken for updating the link quality matrix. Signals are sent by both the transmitter and the receiver to the relay to acquire the link quality of each point. The data contained in the signals includes the information about the sender which includes the signal strength S and the transmission start time. Signal loss along the path is obtained. After getting the receiving quality R_o from the transmitter point o and R_c from the receiver point c, the link quality value for the current location is calculated. The procedure ends if the current location is identified as the optimal one. Else, the relay moves to the next location.

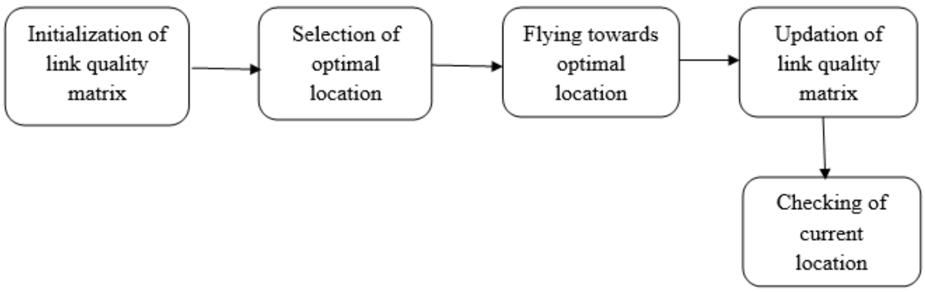

Figure 1. Procedure to find optimal location

3. Conclusions

In the simplest scenario, a communication system consists of a transmitter and a receiver. Effective communication takes place only when the messages send by the transmitter reaches the receiver and the receiver is successful in decoding the message. If the distance between the transmitter and receiver is greater than their transmission range, communication does not takes place. Relays become an important factor in this scenario.

The method reviewed is used to bypass the obstacles or prolong the communication range to compensate for the disconnection between transmitter and receiver. An Auto Relay method which samples the real-time link qualites and keep updating the matrix is designed to quickly determine the optimal location so as to tackle the challenges of accurate location determination.

References

[1] Linghe Kong, Linsheng Ye, Fan Wu, Meixia Tao, Guihai Chen, Athanasios V. Vasilakos, Autonomous Relay for Millimeter-Wave Wireless Communications, *IEEE Journal on Selected Areas in Communication*, 2017

[2] Zhouyue Pi and Farooq Khan. , An Introduction to Millimeter-Wave Mobile Broadband Systems.,*IEEECommunications Magazine* ,2011.

[3] T. S. Rappaport, R. W. Heath, R. C. Daniels, and J. N. Murdock ,. Millimeter wave wireless communications,,2015

[4] S. Geng, J. Kivinen, X. Zhao, and P. Vainikainen , Millimeter-wave propagation channel characterization for short-range wireless communications. , *IEEE Transactions on Vehicular Technology*,2009; 58(1):313

[5] Y. Zhu, Z. Zhang, Z. Marzi, C. Nelson, U. Madhow, B. Y. Zhao, and H. Zheng. ,Demystifying 60GHz outdoor picocells ,*Synth. Lectures Data Manage.* , 2014

[6] G. Kramer, M. Gastpar, and P. Gupta ,Cooperative strategies and capacity theorems for relay networks,*IEEE Transactions on Information Theory*,2005; 51(9):30373063

[7] K. Liu and M. Tao, Generalized signal alignment: On the achievable DoF for multi-user MIMO two-way relay channels,*IEEE Transactions on Information Theory* , 2014;61(6):33653386

[8] R. Wang, X. Yuan, and M. Tao ,. Degrees of freedom of MIMO multiway relay channel with clustered pairwise exchange,*IEEE Journal on Selected Areas in Communications*,2015;33(2):337351, 2015

[9] M. F. Pinkney, D. Hampel, and S. DiPierro . Unmanned aerial vehicle (UAV) communications relay,*In IEEE MILCOM*, 1996

[10] P. Zhan, K. Yu, and A. L. Swindlehurst Wireless relay communications with unmanned aerial vehicles: Performance and optimization,*International Journal of Computer Applications*,IEEE Transactions on Aerospace Electronic Systems

[11] L. Chen, Y. Huang, F. Xie, Y. Gao, L. Chu, H. He, Y. Li, F. Liang, and Y. Yuan, Mobile relay in LTE-advanced systems,*IEEE Communications Magazine*,51(11):144151, 2013..

[12] D. L. Donoho, Compressed sensing,*IEEE Transactions on Information Theory*, 52(4):12891306, 2006.

[13] FCC , Millimeter wave Propagation: Spectrum Management Implications,*, Office of Eng. and Tech., Bulletin no. 70, July*, 1997