Towards a Virtual Reality Home IoT Network Visualizer

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ABSTRACT

We present an IoT home network visualizer that utilizes virtual reality (VR). This prototype demonstrates the potential that VR has to aid in the understanding of home IoT networks. This is particularly important due the increased number of household devices now connected to the Internet. This prototype is able to function in a standard display or a VR headset. A prototype was developed to aid in the understanding of home IoT networks for homeowners.

Index Terms: Human-centered computing—Visualization—Visualization techniques—Treemaps; Human-centered computing—Visualization—Visualization design and evaluation methods

1 INTRODUCTION

With the increased number of household devices now connected to the Internet, the personal data of the typical home-user will be increasingly tethered to the Internet of Things (IoT). Many users are sorely unaware of the personal data potentially leaked by these IoT devices in their home. Users are forced to trust that the devices on their network are behaving in a secure manner with little information regarding when, how, and to who their devices are communicating. We approached this problem with the assumption that the end-user does not have any formal understanding of computer networking. We therefore decided it best to work towards an intuitive visualization to give the typical home-user a better understanding of their own IoT device communications. We were able to identify two major questions while designing a visualization as such. Firstly, where does device network traffic get collected and processed? Secondly, with so much network traffic being produced, how can the user understand an effectively use the visualization without any background information in computer networking? We moved towards finding a solution to these questions through designing a 3D user interface (3DUI) to display IoT device network traffic. This system is able to function in a standard display or a virtual reality (VR) headset. A prototype was developed with the purpose to show this proof of concept where networking students, researchers, and professional can benefit by using this type of visualization. Our main contribution is the ability to showcase a VR networking visualization system with an additional desktop version of the same.

2 RELATED WORK

Castelli et al. created a visualization dashboard system for end-users [2]. This system was designed to visualize general network information for the home owner. The information provided included network speeds, security and other information related to home network.

Ball et al. developed a system called VISUAL [1]. Their system included 2D graphics to display information. There focus was on the visualization of network traffic in homes that with the assumption that they are vulnerable to cyber-attacks. This has some similarities with our system with the difference that the information is displayed using 2D user interfaces (leading to a notably cluttered display).

Some of our design decisions were influenced by ideas presented by Le Malécot et al [4]. They found that visualizing network data can be extremely confusing and cluttered when display in 2D user interfaces. 3DUIs provide a more intuitive understanding of the network packets and nodes. Additional work in this area can be found in [3, 5].

3 VIRTUAL REALITY NETWORKING VISUALIZATION

Our prototype system is comprised of two main components. The first is a back-end server that handles the collection, parsing, and querying of network traffic. The second component is a front-end program that produces a dynamic visualization of the network traffic based on data streamed from the back-end server.

Currently, the collection of network traffic is facilitated by the back-end server. The server communicates with a machine utilizing host access point daemon (hostapd) to act as an access point for several real IoT devices. When the server desires to collect network traffic data from the IoT devices, it will remotely run a script on the access point and pull the data back to the server. This collected data is then processed accordingly and placed into a database to be queried by the user from the front-end. When the back-end server processes collected data, it keeps a cache of identified device specific information to be leveraged on the front-end, such as vendor identification or location. It should be noted that every record placed into the database is a list of features that describes a single network packet that passed through the access point, device specific information included.

The packets collected can be moving out or into the local area network or also packets moving between devices within the local area network. Therefore, the system is able to examine any traffic that leaves, enters, or exists within the local area network (LAN). The back-end server is able to communicate with any number of front-end clients, whenever a client requests data. We have developed a custom method of streaming data to front-end clients that allows for responsive queries regardless of the amount of data returned. For every data request, the back-end server dynamically
The visualization, as shown in Figure 1, provides an interactive user experience that allows exploration of nodes and individual network packets, setting our work apart from existing networking visualization techniques. The ability to have an interactive VR experience, users can appreciate networking information as never seen before. For example, the ability to understand that a HTTP message is traveling from multiple routes while using the virtual environment (VE) provided, gives a sense of immersion while understanding networking.

As already mentioned, we have two prototypes. A desktop 3DUI version and a virtual reality version. While the desktop 3DUI version provides interesting information, it is the virtual reality experience that allows the immersion of the user. While no formal testing was conducted at this stage, people have interacted with the system. Even for people with no networking experience, found the VR system useful to understand packets and internet traffic. In particular, networking professionals from [Company1] and [Company2] were interested in the potential that this project has. However, at the current state of this project, the desktop version was easier for interaction. Yet, the VR environment interaction can be improved as we plan to test further with more users.

The system was developed in Unity Game Engine using an HTC Vive. The desktop version, also developed in Unity, was conducted at this stage, people have interacted with the system useful to understand packets and internet traffic. In particular, networking professionals from [Company1] and [Company2] were interested in the potential that this project has. However, at the current state of this project, the desktop version was easier for interaction. Yet, the VR environment interaction can be improved as we plan to test further with more users.

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As the home environment becomes increasingly connected to the Internet, there is a need to increase the general public’s understanding of how their IoT devices interact with entities outside and within their local area network. We believe that the visualization system presented will make a difference in the understanding of these IoT networks.

5 Conclusion

As the home environment becomes increasingly connected to the Internet, there is a need to increase the general public’s understanding of how their IoT devices interact with entities outside and within their local area network. We believe that the visualization system presented will make a difference in the understanding of these IoT networks.

References

[1] R. Ball, G. A. Fink, and C. North. Home-centric visualization of network traffic for security administration. In Proceedings of the 2004 ACM Workshop on Visualization and Data Mining for Computer Security, VizSEC/DMSEC ’04, pp. 55–64. ACM, New York, NY, USA, 2004. doi: 10.1145/1029208.1029217

[2] N. Castelli, C. Ogonowski, T. Jakobi, M. Stein, G. Stevens, and V. Wulf. What happened in my home?: An end-user development approach for smart home data visualization. In Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems, CHI ’17, pp. 853–866. ACM, New York, NY, USA, 2017. doi: 10.1145/3025453.3025485

[3] Y. Jeong, H. Joo, G. Hong, D. Shin, and S. Lee. Aviot: web-based interactive authoring and visualization of indoor internet of things. IEEE Transactions on Consumer Electronics, 61(3):295–301, Aug 2015. doi: 10.1109/TCE.2015.7298088

[4] E. Le Malécot, M. Kohara, Y. Hori, and K. Sakurai. Interactively combining 2d and 3d visualization for network traffic monitoring. In Proceedings of the 3rd International Workshop on Visualization for Computer Security, VizSEC ’06, pp. 123–127. ACM, New York, NY, USA, 2006. doi: 10.1145/1179576.1179600

[5] E. S. Poole, M. Chetty, R. E. Grinter, and W. K. Edwards. More than meets the eye: Transforming the user experience of home network management. In Proceedings of the 7th ACM Conference on Designing Interactive Systems, DIS ’08, pp. 455–464. ACM, New York, NY, USA, 2008. doi: 10.1145/1394445.1394494