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Poster: Securing IoT Through Coverage-Bounding Wireless Communication With Visible Light

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Abstract—We propose a concept of coverage-bounding and ‘visual’ wireless communication—HODOR—to secure the Internet of Things (IoT). Coverage-bounding means the communication coverage is controlled accurately in 3-dimensions. ‘Visual’ implies that the communication coverage and process are visible to user, representing an important and user-friendly side-channel for securing IoT. HODOR can provide secure wireless communication both psychologically (visible to users) and technically (nodes only communicate with each other within their delimited coverage). It can benefit IoT applications for secure wireless communications, especially those that demand secure interactions in proximity.

I. INTRODUCTION

As the number of Internet of Things (IoT) devices increases rapidly, many efforts are being spent on preventing IoT threats. We propose HODOR, a coverage-bounding wireless communication system to secure IoT. The coverage-bounding is defined as: the wireless communication range is controlled accurately in 3-dimensions. As a result, potential IoT attacks would only occur in the delimited area. The main challenge in HODOR is how to bound the communication range accurately. To achieve that, we will exploit the directionality property of light and the emerging Visible Light Communication (VLC) technology.

Potential applications. Due to HODOR’s properties of being visible and coverage-bounding, it can enhance the security of wireless communication both technically and psychologically. It can secure many IoT applications. For example, secure “watch-to-enter” access control (people open a door at several meters away from it by looking at the door-controller to send the necessary credentials; the door-controller can delimit its allowed access coverage; when exceeded, even people that have the correct credentials cannot open the door), convenient and secure payments in supermarkets (not needed to approach super close to “touch” a Reader for secure payment), and robot control in smart factories (robots are allowed to access certain resources through communications/interactions in proximity only if they are physically located in the delimited areas).

II. THE CONCEPT OF HODOR

HODOR aims at enhancing the security of IoT applications. The key enabler is the bounded wireless communication range, delimited by nodes with accurate methods. It provides secure wireless communication both psychologically (users are aware of the communication process) and technically (nodes can only communicate with each other within their delimit coverage).

Fig. 1: Illustration of the proposed coverage-bounding wireless communications. Nodes can only talk with each other when in their delimited coverage. Different shapes, e.g., sector, denote the coverage delimited by the corresponding nodes.

III. REALIZING HODOR

We propose two categories of preliminary methods to realize HODOR: physical methods and software-defined methods.

Physical methods. Here we exploit the physical properties of nodes and surroundings. Visible light is very directional. As a result, the direction of VLC signals is easy to control. For example, we can use a lens or an opaque tube to control the field-of-view of LEDs at the transmitters (TXs). Similarly, we can simply use an opaque tube at the photodiode of the receiver to only receive light from the delimited directions. Furthermore, visible light cannot penetrate opaque materials. Therefore, surrounding environment such as walls, cabinets, and curtain, can be leveraged to physically bound the wireless

†The name, derived from hold the door, is from the drama Game of Thrones.

‡Even the signals sent by Chuck can reach Alice, if Alice detects that chunk is out of her delimited coverage, she will not decode the packets from Chuck.
the photodiode at the receiver is 90°. A receiver is placed on a desk with a perpendicular distance of 0.35 m from TX1; (2) a cross-shaped cabinet with size 2m × 3m2m, placed in the middle; (3) curtain, with length of 0.5 m and height of 2 m, attached to the cabinet; the dashed line represents curtain. left) Only TX8 is used; right) TX12 and TX32 interfere with TX8 (have same transmission power).

Fig. 4: Experimental validation in our DenseVLC testbed [4]: left) Setup; middle) Only TX8 is used; right) TX12 and TX32 interfere with TX8 (have same transmission power).

communication area. Fig. 1(b) illustrates the use of walls to physically block VLC signals, preventing attacks from behind the wall. When needed, additional blockages can be added to surroundings to bound VLC signals. These methods are similar to isolated servers in which network interfaces are all blocked to prevent all the attacks from the Internet.

Software-defined methods. The second category of methods is software-defined, that can dynamically change the parameter settings of TXs, receivers, and even program the surroundings. LEDs, which are used to carry signals, are normally deployed densely in indoor areas. We could control several neighboring LEDs to transmit constructive/destructive VLC signals to delimit communication areas. If some LEDs modulate their light to interfere with surrounding VLC signals (i.e., in a destructive manner), we can shrink the communication coverage and even create specific shapes of the bounded communication area that can not be achieved with a single LED TX. Another software-defined method is to dynamically change the environment. In RF communication areas, programming the environment and channel through intelligent surface have been proposed very recently to improve the communication performance [1]. Recently, new materials have been developed that can dynamically change between opaque and transparent, e.g., chameleon-like smart glass [2]. These advanced materials could be controlled in software to change the delimited VLC coverage.

IV. PRELIMINARY EVALUATION

Simulation. We build a simulator in Matlab. We consider an area of 3 m × 3 m consisting of a grid of 4 TXs. The TXs are aligned in an array with 2 m inter-TX distance and attached at a height of 2.8 m from the ground, facing downwards. Each TX is equipped with one LED. The half power semi angle of each LED is 15°. The LED data is based on the off-the-shelf CREE XT-E LED [3], which is also used in our experiments. A receiver is placed on a desk with a perpendicular distance of 2 m from the TXs, facing upwards. The field of view of the photodiode at the receiver is 90°.

Fig. 2 shows the simulation results by operating some TXs to send interfering signals. From Fig. 2(b) and (c), we observe that rectangle-shaped coverage-bounding is achieved. By adapting the transmission power of interfering TXs, different sizes of the bounded rectangle can be obtained. Fig. 3 shows the effect of blockages. We consider three blockages: (1) human body, modelled as a cylinder with a 0.40 m diameter and 1.80 m height, and placed 0.35 m from TX1; (2) a cross-shaped cabinet with size 1.5m × 2m × 2m, placed in the middle; and 1.80 m height, and placed 0.35 m from TX1; (2) a cross-shaped cabinet with size 1.5m × 2m × 2m, placed in the middle;