Zigbee and Baymax

Graduate Project 1: The Paper

Eliora Horst

COMP 449: Wireless Network Security

Prof. Corby Schmitz

Loyola University Chicago

INTRODUCTION

Zigbee is a WPAN protocol and IEEE.802.15.4 based specification for a collection of protocols used to create personal area networks for commercial and residential IOT networks. The Zigbee protocol was first conceived in the 1990s, but made official on December 14, 2004 with the ratification of the IEEE.802.15.4-2003. The Connectivity Standards Alliance (formerly the Zigbee Alliance) announced the general release of the Zigbee 2004 Specification (Specification 1.0) on June 13, 2005. Zibgee has had a few major updates since its release, including introducing cluster libraries and retrofitting backwards compatibility. The name itself comes from the idea of a bee flying back and forth, transporting pollen between flowers, just as a packet flows through a mesh network.

STRUCTURE

The three principal components of a Zigbee network are:

Zigbee Controller	ZC	The Controller/Coordinator is the root of the system and acts as an 802.15.4-2003 PAN coordinator full function device (FFD). ZC can also function as routers (ZRs). A Zigbee network always contains a single ZC. The controller can permit nodes to pass through the mesh network and assign logical network addresses. The ZC also stores information, including security keys and other security details.

Zigbee Router	ZR	The router/repeater/range extender is an optional component that can help offload some of the traffic that the ZC would primarily handle.
Zigbee End Device	ZED	The ZED is the end point to any Zigbee system. Depending on the type of network topology of the Zigbee network, it can only communicate with the ZC, or with parent nodes, or with the ZC, ZRs, and other ZEDs. These endpoints are often battery operated, and relatively static (i.e., thermometers, smoke alarms, device embedding sensing, medical data collectors, etc.)

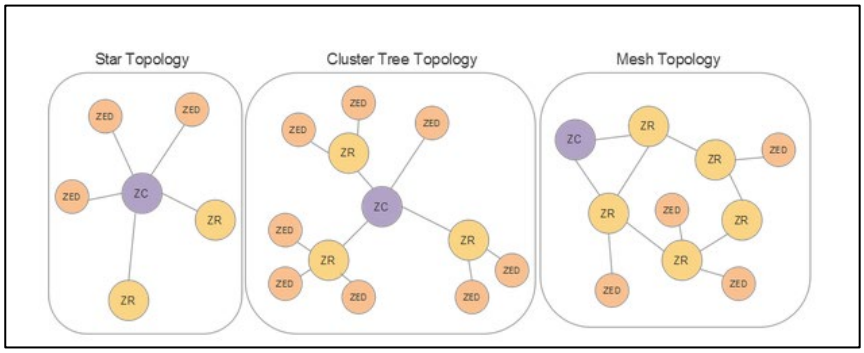


Figure 1: Zigbee Network Topologies, Internet of Things for Architects

A Zigbee network topology can be one of three kinds: star network, cluster tree, and mesh network. A mesh network is the most dynamic, as routing can originate from any source device to any destination device. Star and clusters are used for smaller networks, that have fewer devices (as low as one endpoint), though present issues with communication, and reduces the number of failure points. With a mesh network, multiple ZEDs can communicate to each other, through a ZR, or directly to the ZC.

THE KROGER BAYMAX

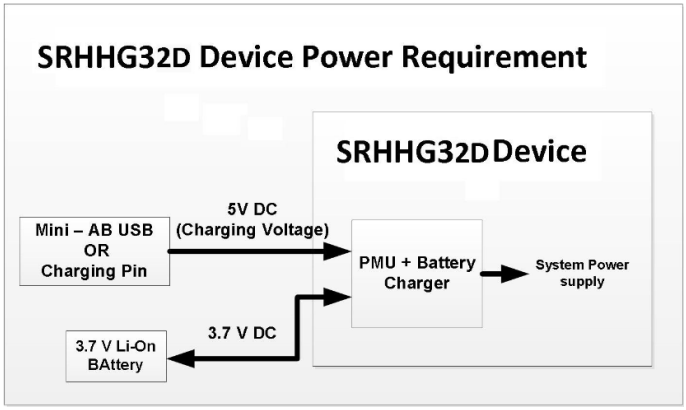
In February of 2015, The Kroger Co. announced they had launched a new technology architecture enterprise with Wincor Nixdorf and eInfochips called Retail Site Intelligence (RSI), aimed at improving store analytics, loss prevention, and store automation. Much of the new technology introduced to stores relied on Zigbee networks, including wireless scanners, temperature sensors, cameras, scales, and more. This enterprise was praised by John Osborne, chairman of the Zigbee Alliance at the time, who ended his statement with "Using our open, global standard will bring the benefits of Internet of Things for retailers and their customers." (Progressive Grocer) While many ZEDs remain relatively stationary, an example of a less static device is the Kroger Baymax handheld, officially titled 'G3HH2D Zigbee Retail Handheld'.

DEVICE SPECIFICATIONS

The G3HH2D Zigbee Retail Handheld contains two Zigbee modules, placed in the upper corners of the board for wireless connectivity to the store's network. The device is only usable inside the store. RF exposure was tested and found not to be harmful.

Figure 2: Internal Top Front View, FCC Wireless Application

Frequency Range	2.405-2.48 GHz (Standard Zigbee range is in the 2.4 GHz ISM band)

Power Output	2.58 mW
Processing	456-MHz ARM926EJ-S RISC Core SoC 256MB DDR2 RAM 256MB NAND FLASH FCC Certified ZigBee Modules (2)
Power	Internal Battery: Input Voltage: 3.7 V@2100mAH Li-Io Battery Input Current: 450mA (MAX.) Battery can be charged either through a docking station or battery charger.  *Figure 3: Power Requirements, User Manual*

DEVICE FUNCTION

Figure 4: External Front View, FCC Wireless Application

The primary function of this ZED is to pick grocery orders for their online grocery pickup/delivery service, *Pickup* (formerly *ClickList*). Customers place their orders via the website or the app, and that data is sent to the store's system, where it assigns orders an ID number and sorts their groceries into four groups: ambient, refrigerated, frozen, or oversized. All Baymax devices are held

in a holding rack that charges the ZEDs via pins. When an employee is ready to shop, they print out a "run" of labels (up to six at a time for regular runs, possibly more if an oversized run), and attach them to collapsible totes stored in a trolley. Each of these labels corresponds to a specific order ID. The employee then scans their personal employee barcode using the Baymax which logs them into the system. Their pick times (e.g., shopping speed) and other data are recorded and sent back to the store system. To start a run, they scan the any label in their run, which prompts the Baymax to enter it's shopping mode. Product details are transferred through the Zigbee network through the nearest access point. For each item, the Baymax shows several key pieces of information:

Figure 5: Baymax device in use, u/FizziSoda on Reddit

1. Location of the item: the code for item is Aisle#.Side.Bay#.Shelf#.Place#. In figure 5, the location of the item is 16.R.1.1.1, meaning the item is in aisle 16, on the right side, first bay, bottom shelf, first item.
2. Customer comments: The top of the main window will display any comments the customer has entered to inform the shopper. This often includes requests for possible substitutions if the requested item is out of stock.
3. Order ID
4. Name of product
5. Last five digits of the UPC
6. Quantity of item
7. BOH: Back of house, or how many are in stock in storage (and from this author's experience, usually incorrect)

To shop for an item, the employee finds it in the store, scans either the item itself or the barcode on the shelf tag, then places the item into the correct tote and scans the tote label. Items can also

be substituted if they are out of stock, or removed from the order altogether if the customer indicated they wanted no substitutions. All this is done through the interface on the Baymax. When a run is completed, the employee returns to the staging area and scans each tote with it's corresponding area and scans to the area barcode to finish the shopping. The Baymax device can also be used to scan items to find their location in the store; these locations are never concrete, as stores change their product layout on a weekly basis.

The Baymax allows employees to relay information directly back to the system, as well as receive information about every single grocery item in the store. It also links employee's personal information directly to their work, so their performances can be recorded and evaluated. It is not a perfect system – often items have been shifted by a little (a shelf or two) or a lot (a different aisle); seasonal items are often not assigned locations, and seasonal stock is not as well tracked; backroom stock is not updated often, and BOH amounts are often incorrect. The Baymax handheld certainly allows for swifter shopping by employees, and connects them far more closely with the in store system than ever before. However, like with many established institutions, there are parts of their technology infrastructure that remain woefully behind (the internal stock system still uses MS DOS), while other parts speed ahead, and the disconnect leads to a lot of confusion in the middle.

WORKS CITED

All information concerning the functionality and usage of the Baymax device in stores is from personal experience as a ClickList employee, at King Soopers in Louisville, CO, from 2017-2019.

FizziSoda. (2020, August 9). *(It was on aisle 16)* [Reddit Post]. R/Kroger. www.reddit.com/r/kroger/comments/i6h68a/it_was_on_aisle_16/

IoT-Inspired Innovation. (n.d.). Retrieved February 5, 2023, from https://www.retailsupplychaininsights.com/doc/iot-inspired-innovation-0001

Kroger Unveils ZigBee-based Retail Site Intelligence Platform. (n.d.). Progressive Grocer. Retrieved February 5, 2023, from https://progressivegrocer.com/kroger-unveils-zigbee-based-retail-site-intelligence-platform

Lea, P. (2018). Zigbee. In *Internet of Things for Architects* (p. 524). Packt Publishing.

The Kroger CO. *FCC ID PBR-SZHHG32D G3HH2D Zigbee Retail Handheld by The Kroger Co.* FCC ID. Retrieved February 5, 2023, from https://fccid.io/PBR-SZHHG32D

The Kroger CO. *SZHHG32D G3HH2D Zigbee Retail Handheld RF Exposure Info RF-Exposure The Kroger*. FCC ID. Retrieved February 5, 2023, from https://fccid.io/PBR-SZHHG32D/RF-Exposure-Info/RF-Exposure-3741382

Zigbee. (2023). In *Wikipedia*. https://en.wikipedia.org/w/index.php?title=Zigbee&oldid=1135335140