Digital Twins and Decentralized Pricing for ESLs

Sandeep Shekhawat

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Sandeep Shekhawat
Walmart Labs
Sunnyvale, USA
sandeep.shekhawat@gmail.com

***Abstract*—Electronic Shelf Labels (ESL) are the new way of displaying pricing in the stores. Going digital helps in improving store employee productivity and accuracy in pricing displayed in the stores. However not all retailers can invest in setting up expensive infrastructure for custom shelf labels at scale. This paper discusses how we can use low-cost mobile devices to overcome expensive shelf label infrastructure setup. In addition to that the paper proposes a way to overcome reliability of the low-cost mobile devices to display consistent pricing in the stores. With patchy network connectivity in stores devices can easily go out of sync and end up showing different pricing for the same items. The proposed solution uses an iBeacon/BLE based solution to make sure the mobile devices-based ESLs can build a consensus and show consistent pricing for the merchandise in the store. The paper also discusses how one can build a Digital Twin for the ESLs to track, monitor and correct pricing.**

Keywords—Internet of Thing, labels, Electronics Shelf Labels, Wireless, Bluetooth Low Energy, iBeacon, Digital Twins

I. Introduction

Smart labels or Electronic Shelf Labels in stores are appearing all over the retail stores around the world. However, some of the biggest retailers are still printing paper labels and displaying pricing, mark down information through fixed price tags. One of the biggest adoption of ESLs has been in the electronic retailers where price markup and markdown happens almost like a clock work as new devices get released the older devices go on sale or are significantly reduced in pricing. Also, the price competition and price matching in electronic device world makes a huge case for using ESLs.

ESLs come in different flavors, e-paper, mono graphic, colored graphic, simple price content display, content + price display [2]. Low-cost mobile phones are another option that can be deployed at scale in electronic retailers and mobile phone retailers. The benefit of using low-cost tablets or low-cost mobile phones has multiple benefits. Recycle older inventory and getting a powerful IoT device that can connect wirelessly and update its content wirelessly. Second aspect that this paper will propose is how a group of mobile phones powered ESL can self-detect inconsistent pricing and auto correct themselves. There is a real-world scenario where multiple devices in a store displaying the same products on multiple shelves can go out of sync and end up displaying inconsistent pricing. There could be several reasons for it, network connectivity problems with the access point, temporary interference in high traffic stores etc. In such a scenario we propose that these devices can use the iBeacon/BLE technology which relies on discovering neighboring devices through a Neighbor Discovery Process [1] and build a consensus on a consistent pricing. In an iBeacon [13] environment each device can act as a scanner and emitter of device location. With the information that is emitted each device relays the ID or the price version, the device currently has. This information can then be used to create a pricing version table on each ESL scanner. One can then implement a simple rule-based algorithm to arrive at the most consistent version of pricing across ESLs which represent the same product. Here the guiding principle is that showing consistent pricing for *a product* across the store is more important that showing the latest pricing.

Fig. 1. ESL in a Retail Store environment, Adapted from [6]

II. A case for Low-cost mobile devices as ESLs

Electronic Shelf Labels in a retail environment is not a novel concept. As J Sung points out in his paper [2], Electronic Shelf Labels or Smart Labels are leading to a paradigm shift in retail environment by transforming non communicative, dummy objects into smart objects. The Smart Labels are an application of Internet of Things in the retail space.

However, if a retail store decides to implement Electronic Shelf Labelling, they need to invest millions of dollars before they can get custom built Smart Labels for their needs. They must first solve the design problem, then the manufacturing problem and then distribution problem. And yet, with the changing needs of the Retail environment, these devices may soon become obsolete, or the innovation in these custom IoT devices might be lagging because of the whole lifecycle of design-manufacture-distribute. Some of the players in the ESL markets are Altierre, DisplayData, Pricer, SES-imageotag [5] all of which require custom setup and upfront hardware investment.

On the other hand, there is one innovation which is ubiquitous, highly customizable, has a well-established manufacturing pipeline, and is getting cheaper every year -

the smart phone. Smart Phones are highly customizable because, they have this asset called the display screen which can be adapted to show exactly what you want using mobile phone applications or Apps. Smart Phones have internet connectivity, are extremely customizable using apps, and are available at a very conducive pricing by many manufacturers. Smart phones have very well-established manufacturing and distribution pipelines. For these reasons, this paper proposes Smart Phones are a viable option to use as Electronic Shelf Labels.

Fig. 2. Mobile devices as ESL displaying content and pricing, Adapted from [7]

Some benefits of using mobile phones as ESLs are:

1. Generally, ESLs are cost effective and less time-consuming alternative to paper-based labels. ESLs are cost effective in the long run as they take away the paper printing aspect of pricing. They are less time consuming from price update process as store associates do not need to manually print labels and stick them around the store.
2. Easy availability of n-1 or n-2 generation devices which are significantly lower in cost. Retailers with low margins can use their older inventory as ESLs with reduced investment.
3. Store associate learning curve of device setup would be not as steep as setting up a new hardware in the store.
4. Mobile phones can connect already existing access points in the stores and do not need an overhaul of the in-store WIFI setup.
5. One of the major reasons retailers stay away from ESLs is the time it takes to update content and pricing. With Wireless connection these mobile phones would a decent connection to download Pricing data and basic content that is tied to each product.
6. ESLs drive customer engagement. With Mobile phones which are interactable, customers can navigate content and explore features of a product. This specifically applies to products which have content associated with them which helps them make purchase decision like TVs, size, colors, specification comparison.

III. App DESIGN TO SHOW MARKETING CONTENT AND PRICING

ESLs are easy to maintain and require very little associate involvement after the initial setup is done, however they are only useful for customers if it gives them more information than just pricing. For goods where there are not many combinations based on color, size, specifications showing just pricing is usually sufficient. E.g., T-shirts or clothing. These types of stock keeping unit (SKU)s even with different color and size usually have same prices. Implementing a small ESL is a no-brainer on these products. The most ROI from smart, auto updating ESL with marketing content display, would be for goods like TVs or mobile phones. On these devices, usually customers have a hard time making purchasing decision since there are multiple combinations on color, device screen size, device storage, memory, and camera etc. In such cases a comparison of features with pricing helps makes a purchase decision and customer conversion. We recommend deploying a simple content + price display app on these low-cost mobile devices which can serve as a place to show all goods related data.

Two challenges that arise out of this:

1. How do we track which device is tied to which item/product in the store and how do we update/push the right content + pricing to the right devices?
2. How do we setup the initial devices correctly?

We propose the following the solve this:

Taking the example of a shelf table displaying iPhone that are being sold. When setting up the mobile based ESL initially we tie the device to a catalog id and a SKU Id. SKU id is normally used as a primary key identidy a specific type of aproduct sold on the sales floor. In this case we use the SKU id to uniquely identify the item against which the ESL is displayed. High level e.g., of this would be Catalog = iPhone, SKU Id = iPhone 8, SKU Id = iPhone 9, SKU Id = iPhone 10 etc. The only setup that's needed initially is store associate selecting the Catalog and SKU id that needs to be displayed. This information can then be relayed back to the server which can push the right set of content + pricing data for that specific SKU to that device. Catalog information can be sent back to the server using a HTTP based connection from client to server.

A. Abstract System Design

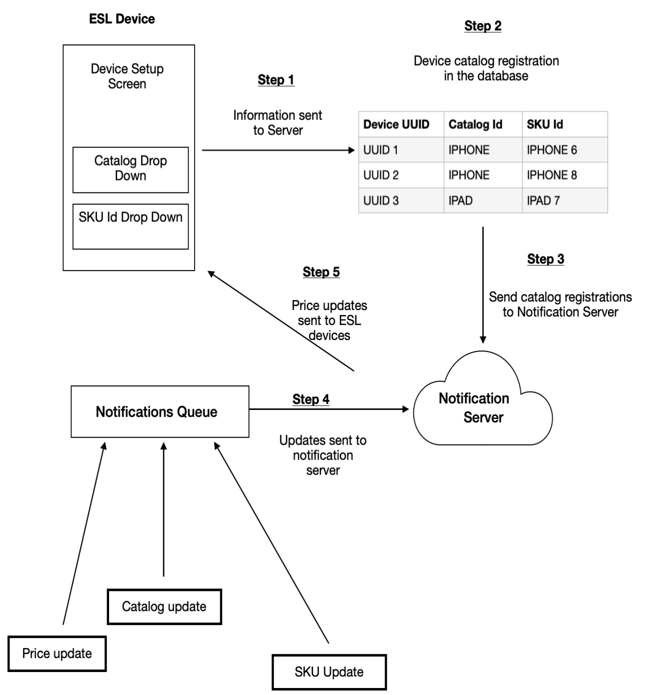

Fig. 3. Abstract system design to track ESL UUID to Catalog Id and SKU Id

B. *Application Mockup Designs*

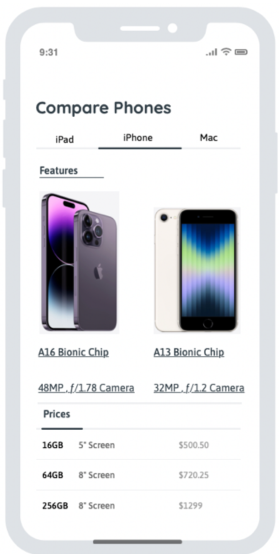

Fig. 4. Sample app to show price comparison, Adapted from [8]

IV. CONSENSUS BASED PRICING CONSISTENCY

One of the realistic scenarios in retail stores setting in WIFI network connectivity problems. While a lot of progress has been made in retail connection space there are a lot of stores spread on huge lots and networks in the stores are patchy or intermittent certain parts of the stores. While auto updated pricing, content and SKU information over the air are benefits of ESLs, the same ESLs can suffer from connectivity issues and suffer stale pricing in some or all ESLs deployed for a specific product. This section of the paper will build upon the work done in [1] to use Bluetooth Low Energy and the Neighbor discovery process to recover from inconsistent pricing and make sure that all ESLs are showing consistent pricing. One thing to call out is showing consistent pricing for the same product is far more important than showing the most current pricing. From my experience in building Retail applications both from customer associate and customer's perspective consistent pricing is the best recovery scenario. For Customer Associate they do not have to do anything in the store if the devices loose connectivity as all ESLs will always be guaranteed to show same pricing for same product. For customer the experience will not be confusing if they see a phone for $999 on one ESL and $899 on another ESL.

Let's take an example of 4 ESLs deployed on a table which can go out of sync showing pricing.

Scenario 1: Complete store has connectivity issues, and all ESLs are unable to connect to the WIFI access point.

Scenario 2: A few access points have connectivity issues which could result in few ESLs for a product to have stale pricing.

A. *Recovery in case of Scenario 1:*

This is a simpler state to recover from. In this case all devices would be disconnected around the same and barring the edge case where a device might be in-flight updating its content, all ESLs will have same content and pricing.

B. *Recovery in case of Scenario 2:*

This is a bit tricky state to recover from, however we can use the Neighbor Discovery Process (NDP) process described in [1]. The general idea is that through NDP the 4 devices maintain a table of the pricing version that's currently shown on each ESL. In case of iPhone which support iBeacon [13] [14] one can setup the app described in I to easily emit a particular beacon id and the pricing version it has. The same will be done by all other devices which are also setup to listen to nearby beacons and emit their pricing version. Since this is low energy Bluetooth, this communication is not impacted by the WIFI access point connection issues.

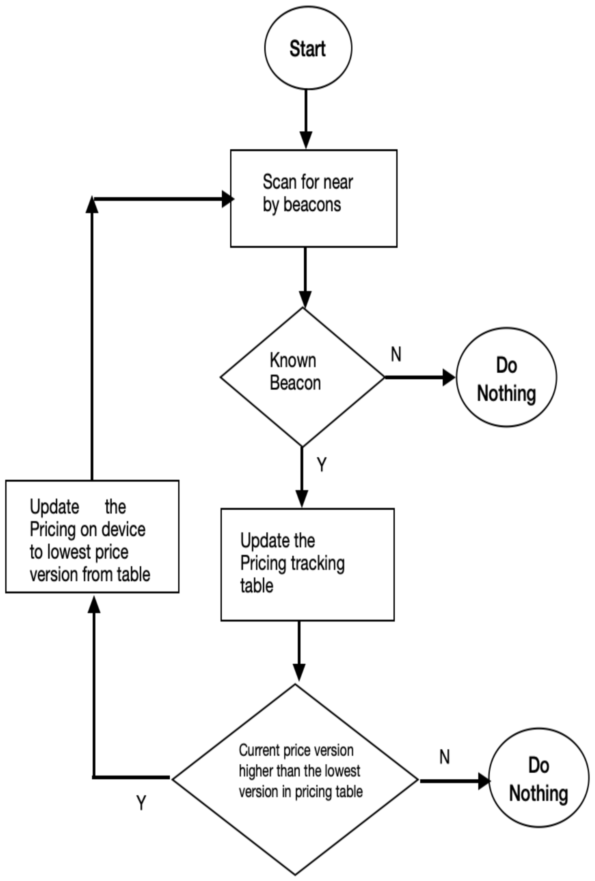

Fig. 5. Flowchart to decide when to fall back to lower version of pricing

In the figure below you will see once the devices have run the scan and emit process multiple times as long as a strong BLE communication remains feasible the devices will converge on consistent pricing across all of them.

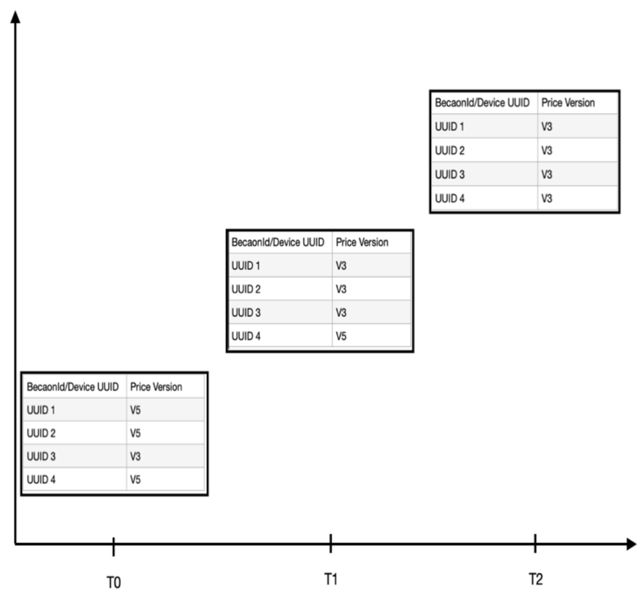

Fig. 6. Timebased cached price table updates on ESLs

The above algorithm and solution propose that device fall back to the lowest version of the cached pricing seen across all the ESLs for consistency. The solution also assumes that the ESLs will have enough storage to store up to X number of older price versions which can be identified after running tests in a simulated store environment. Mobile phones have decent storage in these days which can go up to GBs. An average pricing information at max would in few KBs if not bytes. This will be more than sufficient to store 100's of pricing versions on device in the local storage.

V. What is Digital Twin and How to use a digital Twin in Retail

A digital twin is a virtual representation of a physical process, product, or system. It is a digital copy that allows organizations to observe, analyze, and experiment with different scenarios and approaches. Digital twins can be used to model a wide range of systems, including manufacturing processes, supply chains, and infrastructure.

In the retail industry, digital twins can be used to optimize various processes and improve decision-making. For example, a digital twin of a store's inventory system can be used to simulate different stocking and replenishment strategies, allowing retailers to determine the optimal approach. A digital twin of a store's layout can be used to model different merchandising and display strategies, helping retailers to optimize the customer experience [18].

Digital twins can also be used to improve pricing accuracy and reduce losses due to incorrect pricing. By using real-time data from in-store sensors and other sources, a digital twin can track and update product pricing in real-time, helping retailers to avoid costly errors and lost revenue. In addition, digital twins can be used to monitor and analyze customer behavior, allowing retailers to better understand their customers' needs and preferences.

There are several benefits to using digital twins in the retail industry. First, they allow retailers to experiment with different scenarios and approaches without incurring the costs and risks associated with implementing changes in the physical world. This can help retailers to identify and implement the most effective strategies. Second, digital twins can help retailers to optimize their operations and decision-making by providing real-time data and insights. Finally, digital twins can help retailers to reduce losses due to incorrect pricing and other issues, leading to improved financial performance.

Overall, digital twins are a powerful tool that can be used to optimize various processes and improve decision-making in the retail industry. By providing real-time data and insights, digital twins can help retailers to better understand and serve their customers, while also improving operational efficiency and financial performance.

VI. Experiment Setup

To demonstrate the capabilities of digital twins in collecting and analyzing data, one can conduct an experiment using any cloud technology, e.g. Microsoft Azure Digital Twin platform. The experiment will involve setting up a digital twin of a retail store and using sensors to collect data on various aspects of the store's operations, such as foot traffic, customer behavior, and product sales.

First, step would be to set up the digital twin in Microsoft Azure. This will involve creating a virtual model of the store, including its layout, products, and other relevant details. We will then set up sensors in the physical store to collect data on various aspects of the store's operations. These sensors could include cameras to track foot traffic, RFID scanners to track product sales, and other sensors to collect data on temperature, humidity, and other environmental factors.

Next, one can configure the digital twin to collect and analyze the data from the sensors. This will involve setting up rules and algorithms to process the data and generate insights. For example, we could use machine learning algorithms to analyze the data on foot traffic and customer behavior to identify patterns and trends. We could also use the data on product sales to optimize the store's inventory and replenishment strategies[19].

Once the digital twin is set up and collecting data, we can conduct various experiments to test its capabilities. For example, we could change the layout of the store or introduce new products to see how these changes impact foot traffic and sales. We could also use the digital twin to simulate different pricing scenarios and see how they impact customer behavior.

Another idea would be to try different Wifi network conditions in the store and see how ESLs are showing the pricing. Through Digital twins collected data and applying anomaly detection one can easily predict which ESLs are potentially showing incorrect pricing or could show incorrect pricing.

Throughout the experiment, one can monitor the performance of the digital twin and analyze the results of the various experiments. This will allow us to determine the effectiveness of the digital twin in collecting and analyzing data, as well as its ability to provide insights and inform decision-making around pricing. We can also use the results of the experiment to identify areas for improvement and refine the digital twin and the ESLs as needed.

VII. Future SCOPE

Mobile based shelf labels are easy to implement, deploy and have the advantage of content display in them. One of the future scopes of work is to explore content in e-paper display ESLs. The cost effectiveness of e-paper based ESLs is much higher therefore, future work should compare how can a e-paper ESL display content and make it interactable for users.

VIII. Conclusion

Digital transformation of Retail world is happening in front of us. From Scan-n-go to curbside pick-ups, Retail world is bridging the gap between online and physical store. Customers are starting to expect an omnichannel experience in the store. Customers expect to see the price they see online in physical stores too. ESLs play a big part in Digital transformation of these Retails stores. They help bring the omnichannel pricing experience in the stores. ESLs also remove one of the most common activities for store associated in stores which is price updates, price mark downs, label printing, incorrect price fixing etc through automation. This paper explores using existing low-cost mobile phones as ESLs. The paper also proposes a decentralized way to avoid displaying incorrect or inconsistent pricing across the ESLs for the same product. By using this framework, mobile phones can be treated as IoT devices and updates with content, price, and SKU over the air in a very reliable way.

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