CHIP

CHAIN INTEGRATION PROJECT

AUBURN UNIVERSITY

RFID LAB

PROOF-OF-CONCEPT

WHITEPAPER

FOREWORD

Michael Graen
Owner - Collaboration LLC

One of the great honors in my career was to be part of the inaugural Procter & Gamble-Walmart Customer Team in 1989. In those days, the relationship between our team at P&G and Walmart was adversarial, transactional and filled with excessive, unproductive work. I had a chance to meet and work with Mr. Sam Walton, the founder of Walmart stores. During one of our earliest discussions, he looked at me and offered some sage advice:

“Mike, if you (P&G) thought of your company as an extension of our stores… you would treat us a lot different. Can’t you just send us product and we will send you money?”

Such a simple concept, and yet frustratingly difficult to achieve. I have had the opportunity to spend my entire 30-year career in the world of retail, primarily focusing on supply chain and information technology solutions. I have worked for a supplier (P&G) and retailer (Walmart), and can confidently say that engagement between Consumer-Packaged Goods (CPG) companies and retailers has been largely unchanged for three decades. The technology behind Purchase Orders, Advanced Shipment Notifications, and Invoices has slowly evolved from hardcopy documents sent through the postal service to fax machines to EDI. We have spent so much time and effort speeding up the process of moving data back and forth, but the accuracy and harmony of this information was rarely researched.

Though they will rarely admit it in front of their trading partners, almost all retail CPG executives will acknowledge accuracy and synchronization of this information is flawed. An early study in 2017–2018, Project Zipper, compared the accuracy of Advanced Shipment Notifications to the actual item content of the cases shipped, and showed that 69% of ASNs do not match the purchase orders. This is a system that isn’t in need of faster data, it needs total re-invention.

Following these early learnings, the Chain Integration Project (CHIP) was initiated to provide a vision into the future of information exchange between suppliers, retailers, and other supply chain stakeholders. It provides an automated process of leveraging serialized data between trading partners using automated data collection methodology that eliminates the need for human audits and counting. The CHIP proof-of-concept proved that suppliers and retailers can exchange serialized data using blockchain to increase visibility into product flow.

When the CHIP team at the Auburn University RFID Lab began its mission in early 2018, their first task was to scope the opportunity. They identified a tremendous of amount of error and inefficiency in current supply systems, to the tune of $181 billion worth of business potential by eliminating claims, shrink and counterfeiting in the supply chain.

I am proud to be part of this effort with the Auburn University RFID Lab. This is the future of commerce between retailers and suppliers, and I look forward to the next phase of this initiative. The surest way to predict the future is to invent it, and the very best inventions are based on simplicity. “Can’t you just send us product and we’ll send you money?” is as simple as it gets, and I’m proud to be a part of the CHIP effort that hopes to drive our industry back to answering that simple, 30-year-old question.

ABSTRACT

It has been over 15 years since serialized data was introduced to the retail supply chain in the form of RFID Tags, QR Codes, and other data carriers. However, there has yet to be an effective, industry-wide solution for exchanging serialized data between business partners. Traditional EDI (Electronic Data Interchange) networks allow higher-level business documentation to change hands, but these networks operate on outdated models and antiquated internet technologies, rendering them unfit for the massive volumes of serialized data being created throughout the supply chain today. End users and solution providers have been unsuccessful in establishing managed server solutions for serialized data exchange, primarily because of the imbalance of control created by their centralized solutions or the lack of scalability across the industry.

Meanwhile, the presence of serialized data in the supply chain has grown rapidly as more brands adopt source tagging techniques and more stakeholders throughout the supply chain install infrastructure to collect information on products flowing through their facilities. However, the item-level visibility supplied by these systems is constrained by the industry-wide ineptitude for sharing serialized data. As a solution to this problem, the first phase of the Chain Integration Project (CHIP) sought to establish a blockchain network that was capable of sharing item-level data between supply chain stakeholders in the retail industry. The proof-of-concept was designed to ingest serialized data from multiple touch points throughout the supply chain, including encoding, distribution, and store data, with the end goal of determining the feasibility of a Hyperledger Fabric-based data exchange mechanism. Three brands, Nike, PVH Corp., and Herman Kay, as well as two retailers, Kohl's and Macy's, contributed live data to the project.

OVERVIEW

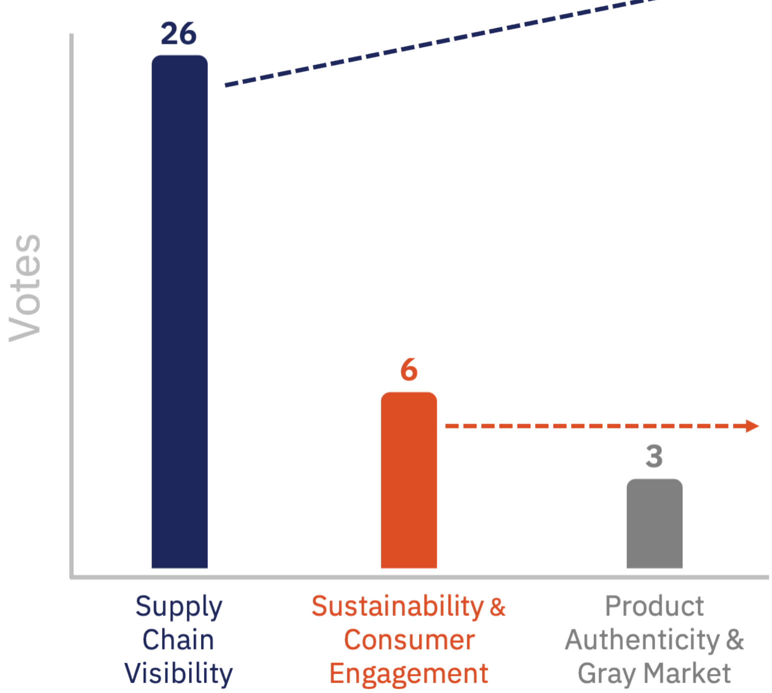
This paper is divided into ten sections. The Business Case for blockchain in retail is explored in the initial section, followed by Participants & Partner Pairs. The three sections afterwards detail the three sequential steps that each partner took throughout the course of the project: 1) Identify Serialized Systems & Stakeholders, 2) Standardize Data Streams, and 3) Integrate Data Streams into the Blockchain. The methodology and results of each step are reported in each section. After the third and final step, Analysis of serialized data on the blockchain is shared. Opportunities for Improvement and Next Steps are shared after a brief Conclusion, and the final section offers Recommendations for implementing blockchain solutions in supply chain.

THE PROBLEM

Current advancements in serialized item data availability and RFID adoption present new business value opportunities. ASN accuracy is poor, and the technology for data exchange is dated and deficient. Additionally, the claims and chargebacks resulting from errors are expensive for all stakeholders. How can we share serialized item data throughout the supply chain, and what is the value in doing this?

BUSINESS CASE

The origins of the CHIP Initiative trace back to the fall of 2016 when Mojix and Microsoft introduced the Auburn RFID Lab to the concept of blockchain in the retail supply chain. After a demonstration of the technology's potential by Mojix and Microsoft at Retail's BIG Show (NRF) in 2017, industry interest continued to grow until the Auburn Blockchain Working Group was established in February 2018 to explore the business case for blockchain in retail. This consortium was comprised of numerous brands, retailers, and logistics providers with support from both major platform providers of the time, Microsoft and IBM. GS1 US was also a founding member of the Working Group. An informal survey was conducted to determine the top use cases for the brands, retailers, and logistics providers represented in the group. The following results are listed in order of highest priority to lowest: Supply Chain Visibility, Sustainability & Consumer Engagement, and Product Authenticity. Supply Chain Visibility was by far the most popular category, receiving nearly 75% of the votes. General supply chain visibility was deemed to be the most important sub-category, while specific use cases like shipment notifications, order validations, and custodial ownership received a significant number of votes as well. Sustainability & Consumer Engagement was the second most popular category, with voter emphasis on products' country of origin and sustainable sourcing practices. Product Authenticity was the third most popular category, with emphasis placed by the group on counterfeiting and gray market goods.



After determining the most relevant use cases, the Working Group began to pinpoint the specific problems that improved supply chain visibility could address. Three chronic pain points were identified. One of the costliest points of contention between brands and retailers is claims and chargebacks. Claims are issued when shipments are damaged, lost, or inaccurate. In 2017, the total amount of chargebacks in the retail, apparel, and grocery industries exceeded $36 billion, or 1% of total retail sales (1). Shrink, or unaccounted for inventory, totaled $47 billion in 2017 (2), partly due to administrative errors and unknown issues throughout the supply chain. Counterfeiting and gray market goods were commonly cited by brands and suppliers as a key concern, with estimated losses due to counterfeit footwear, apparel, and other high-end consumer goods exceeding $98 billion in that same year (3). Altogether, the sum of these three pain points exceeds $181 billion.

Supply Chain Visibility

- 2 cold chain compliance
- 4 supplier network; ASNs
- 5 custodial custody, physical ownership
- 7 expected delivery; overage/shortage verification
- 8 general supply chain visibility

Sustainability & Consumer Engagement

- 1 consumer engagement
- 5 country of origin; sustainability

While there are many factors that perpetuate these problems, a common thread amongst them is that there is little to no communication of serialized data between the stakeholders involved in each issue. Claims are often settled in the absence of sufficient shipment information on both brand and retailer sides, with predetermined rates and paper-based processes guiding the negotiation process. In stores, a significant share of shrink can be attributed to inaccurate information of inbound product that isn't detected further up the supply chain. Efforts to eliminate counterfeiting are complicated when distribution channels are compromised and visibility into product flow is lost in gray markets. All stakeholders affected by these systemic issues stand to gain from enhanced information exchange and greater availability of granular product data.

PARTICIPANTS & PARTNER PAIRS

The CHIP Initiative was supported by a consortium of companies that were organized into the Auburn Blockchain Working Group. Each company was represented by one or more delegates that participated in various sub-groups focused on business case development, data standards, and solution architecture. The participating organizations included Avery Dennison, Checkpoint, Collaboration LLC, Dillard's, Elverston LLC, FedEx, GS1 US, Herman Kay, IBM, Kohl's, Macy's, Microsoft, Mindy Rector Consulting, Mojix, Nike, PVH Corp., Smart Cosmos, SML, Spanx, Tuskegee University, Under Armour, and Zebra Technologies. Collectively, these organizations defined business objectives for the proof-of-concept and outlined the technical requirements for an industry-wide blockchain solution.

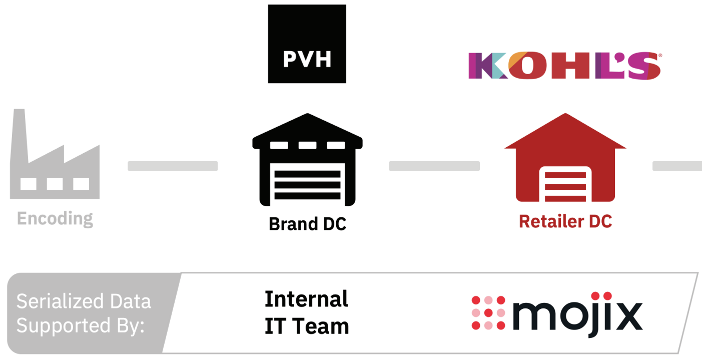
Partners Plugging In to the P-o-C

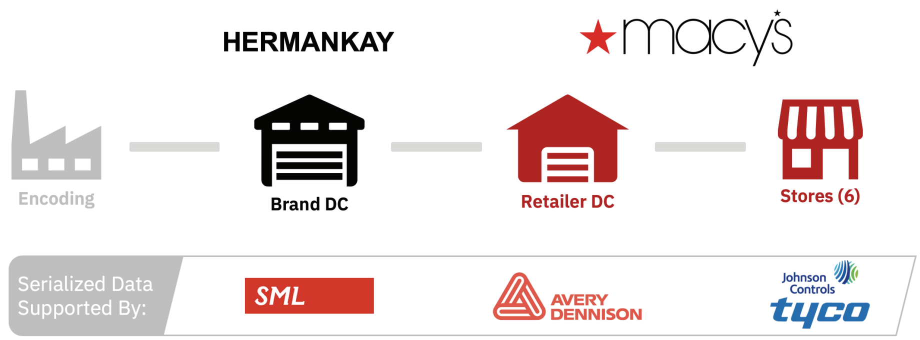
HERMANKAY & macy's

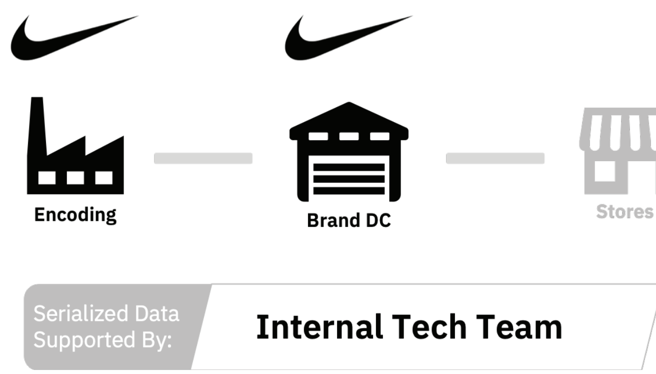
PVH & KOHL'S

Five of these organizations, Nike, PVH Corp., Herman Kay, Kohl's, and Macy's, opted to contribute live supply chain data to the project and "plug in" to the blockchain solution. Those organizations were separated into partner pairs that modeled existing trade relationships. For the course of the proof-of-concept, PVH Corp. and Kohl's were paired together and Herman Kay and Macy's were paired together into traditional wholesale channels. Since Nike operates in a vertical, their encoding and distribution points were considered to be separate operations, effectively representing two distinct entities within the same channel.

STEP 1: IDENTIFY SERIALIZED SYSTEMS & STAKEHOLDERS







The initial step of the project required each partner to identify the degree of serialized data systems in their supply chains. The term "serialized data" refers to any and all forms of SGTIN-level data carried by RFID tags, QR Codes, or 2D Data Matrixes, as well as SSCC or serialized case code information. These serialized data sources provide more granular information than class-level identifiers found in most barcodes. They also ensure item-level singularity, allowing users to identify and trace specific items or cases throughout the supply chain.

The goal for each partner pair was to contribute data from multiple touchpoints ranging from source to store. More specifically, the touch points requested were point of encoding on the brand side, distribution on the brand side, distribution on the retailer side, and stores on the retailer side. In addition to determining which supply chain nodes were capable of contributing serialized data to the project, each partner had to disclose which solution providers supported the various serialized data systems. Including the relevant solution providers early in the conversation was necessary because they often play a central role in serialized data management.

For the PVH-Kohl's partner pair, each partner was able to identify and contribute serialized data from their distribution centers (or DCs). PVH identified two outbound touch points in one of their DCs that would contribute serialized item and case-level information. Both of these touch points reported SGTIN data and case code information related to outbound shipments, and the vast majority of outbound orders were routed through these touchpoints. Kohl's contributed inbound data from a DC that included SGTIN data and case-level data from one receiving lane. Altogether, these two serialized data streams provided visibility into outbound and inbound shipments on either side of the DC-to-DC transaction. PVH Corp.'s serialized data systems were supported by an internal team that managed the infrastructure on-site and manipulated the data streams as needed. Kohl's partnered with Mojix to generate and share serialized data streams from the DC for the course of this proof-of-concept.

For the Herman Kay-Macy's partner pair, both partners identified and contributed serialized data from their distribution centers, and Macy's also contributed serialized data from six stores. Herman Kay, also referred to as 'HK', identified an outbound touch point in their DC that would contribute serialized item and case-level information for all shipments leaving the facility. Macy's contributed inbound receiving data from a DC that included SGTIN data and case-level data, and they contributed cycle count data from six stores that provided SGTIN data. Collectively, the HK-Macy's partner pair had visibility from the brand DC to the retail stores, with eight total supply chain nodes plugging in to the project. In terms of solution providers, Herman Kay partnered with SML to capture and contribute data at the DC-level. Macy's partnered with Avery Dennison at the DC-level and Tyco at the store-level in order to supply serialized data to the project.

Lastly, Nike was able to supply serialized data from the point of encoding and from a DC. The encoding data included SGTIN values and the DC data included SGTIN values as well as case codes from an internal touch point. Nike's own tech team supported these serialized data systems and provided the relevant data streams to the project.

STEP 2: STANDARDIZE DATA STREAMS

The second step of CHIP was to standardize the output of the relevant serialized systems. The need for a uniform language was essential because if a standard was not defined and adopted, the dissimilar data from all the systems would result in the same problems encountered by Project Zipper (4), namely mass amounts of unstructured data that would require considerable resources to clean and compare. Electronic Product Code Information Services (EPCIS) was designated as the standard for this proof-of-concept. EPCIS is a GS1 standard that enables supply chain stakeholders to share transactional information regarding the movement and status of items at various stages in the supply chain. Each EPCIS transaction contains key data elements that communicate what the subject matter of the transaction is, when it is identified, where it is identified, and why it is at that step in the supply chain. EPCIS has become increasingly popular for blockchain solutions that encompass multi-party supply chains. Because Hyperledger Fabric, the blockchain framework used for this project, primarily supports JSON formatting, data in EPCIS format was translated from XML to JSON before being uploaded to the blockchain network. The current version of the EPCIS standard only supports XML formatting, but an updated version of the standard for JSON is expected to be released by GS1 in 2020. One supplementary field, 'hex', was included within each transaction and it represented the hexadecimal EPC value for each item. The hexadecimal EPC, a value encoded from the EPC Pure Identity URI, was used as the primary identifier within this blockchain ecosystem. An example transaction in either format can be seen below.

Step 2 EPCIS Transaction Examples

XML example


```
<EPCISBody>
 <EventList>
  <TransactionEvent>
   <eventTime>2019-06-14T19:54:13.183-04:00Z</eventTime>
   <recordTime>2019-07-01T12:09:58.150-04:00Z</recordTime>
   <eventTimeZoneOffset>-04:00</eventTimeZoneOffset>
   <parentID>urn:epc:id:sscc:0099617.0378886433</parentID>
  <epcList>
     <epc>urn:epc:id:sgtin:0011531.020393.20998782988</epc>
  </epcList>
   <action>OBSERVE</action>
   <bizStep>urn:epcglobal:cbv:bizstep:receiving</bizStep>
   <disposition>urn:epcglobal:cbv:disp:in_progress</disposition>
  <readPoint>
     <id>urn:epc:id:sgln:5012345.67890.1</id>
   </readPoint>
   <bizLocation>
   <id>urn:epc:id:sgln:5012345.67890.2</id>
   </bizLocation>
  </TransactionEvent>
 </EventList>
```


JSON example*


```
{"eventtype": "ObjectEvent", "eventTime": "2019-06-
14T19:54:13.183-04:00Z", "recordTime": "2019-07-
01T12:09:58.150-04:00Z", "eventTimeZoneOffset": "-
04:00", "parentID":
"urn:epc:id:sscc:0099617.0378886433", "epc":
"urn:epc:id:sgtin:0011531.020393.20998782988", "hex":
"301400B42C13EA44E3A0000C", "action": "OBSERVE",
"bizStep": "urn:epcglobal:cbv:bizstep:receiving",
"disposition": "urn:epcglobal:cbv:disp:in_progress",
"readPoint": "urn:epc:id:sgln: 5012345.67890.1",
"bizLocation": "urn:epc:id:sgln: 5012345.67890.2"}
```


*although the current EPCIS standard only supports XML format, it was necessary to transform each transaction into a more "blockchain friendly" JSON format. GS1 is expected to publish formal guidance for EPCIS and JSON in 2020.

Project partners had two options for standardizing the output from their serialized data systems. The first method was to send data as-is to a web application that identified the key data elements within the original dataset and automatically transformed the data into an EPCIS-compliant output. This translation within the web application was developed by the CHIP team and was configured to ingest various data feeds from partners and to return a standardized result. Kohl's, Herman Kay, and Nike opted to use the first method and Macy's utilized this method for its store data stream. Alternatively, the project participants could generate EPCIS-compliant data independently, relying on internal teams or solution providers to perform the transformation. PVH Corp. and Macy's chose this method for the DC data streams that they contributed to the project.

Step 2

Methods for Standardizing Data Streams

Method A: utilize Auburn Translator Tool

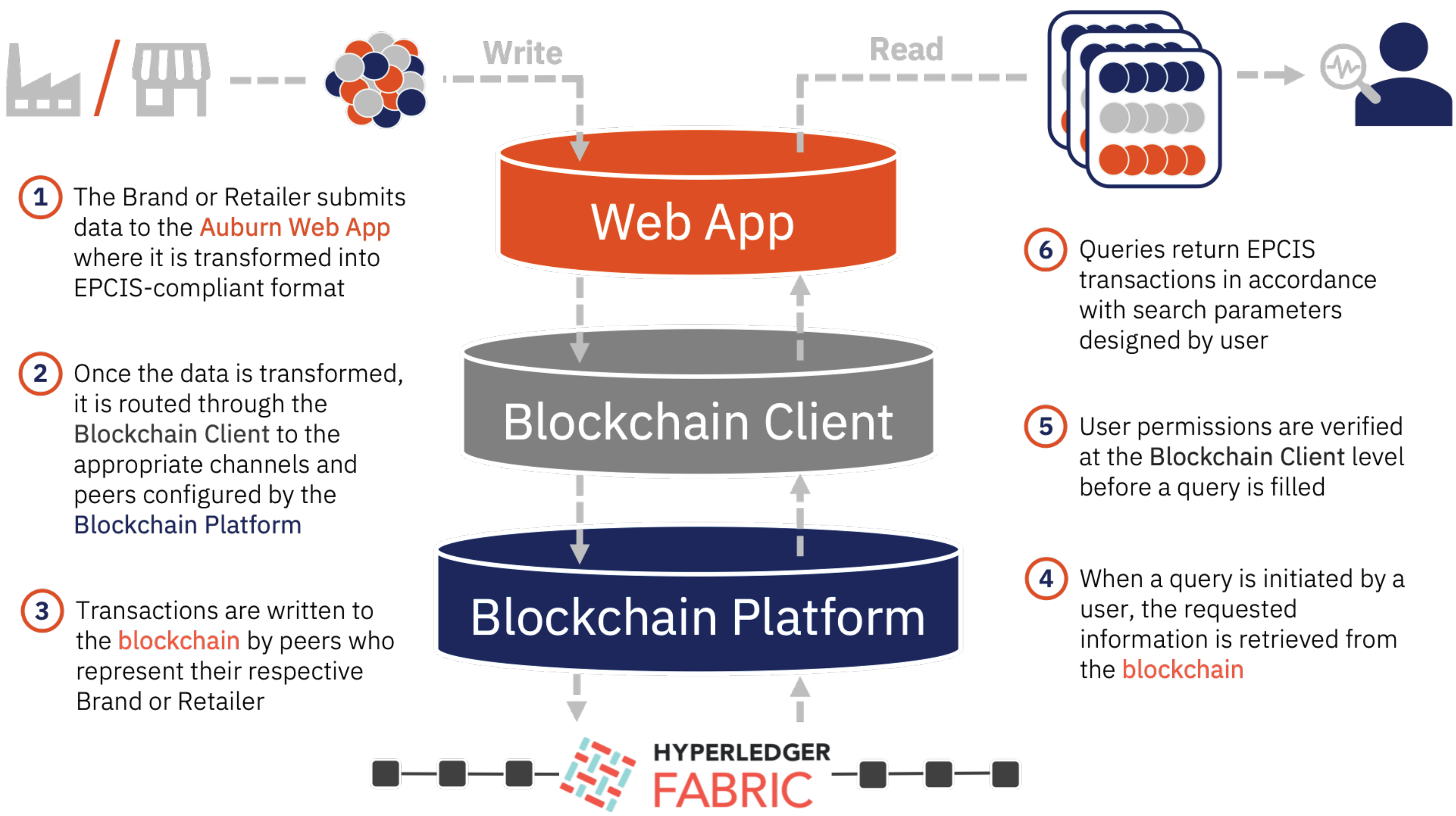
4 partners chose this method: **Kohl's**, **HermanKay**, **Nike**, **Macy's** (stores)

Method B: perform transformation independently

2 partners chose this method: **PVH Corp.**, **Macy's** (DC)

STEP 3: INTEGRATE DATA STREAMS INTO THE BLOCKCHAIN

Once the data streams were standardized, they were integrated into the blockchain. The third and final step of the project was to tie the various data streams into a Hyperledger Fabric-based blockchain network. There were three specific layers of the technology stack that standardized data had to pass through before being embedded in the blockchain. The initial ingestion point was the web application developed by the CHIP team; this is the same web application from Step 2 that performed the EPCIS transformation, and it served as the primary user interface. The second layer of the solution was the blockchain client, which was also developed by the CHIP team. The blockchain client acted as an intermediary between the web application and the blockchain platform by providing API endpoints for either side of the stack, effectively transferring new transactions from the web application to the blockchain and also delivering query results from the blockchain to the web application. The last layer that the data had to pass through before being written to the blockchain was an instance of IBM's Blockchain Platform controlled by the CHIP team. The IBM Blockchain Platform (IBP) was utilized to configure and administer the Hyperledger Fabric blockchain network that this project was built upon. By reducing the complexity associated with Hyperledger Fabric's source code, IBP allowed the CHIP team to seamlessly connect the rest of the stack to the blockchain and also to configure the core components of the blockchain network.

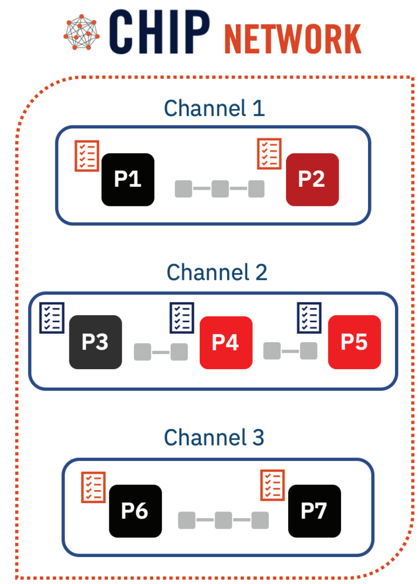


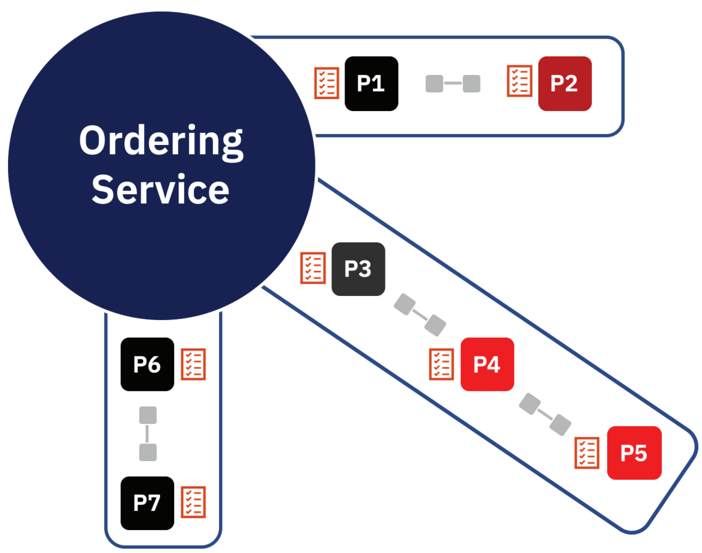
Hyperledger Fabric was the metaphorical backbone of the entire solution, and it was originally chosen as the foundational framework for the blockchain for several reasons. The broader Blockchain Working Group agreed at the inception of this project that data privacy was the most important design consideration when it came time to select a blockchain framework to build upon. Because confidentiality was of utmost concern, Hyperledger Fabric emerged as the most viable solution due to its private and permissioned nature. Hyperledger Fabric is also highly modular, allowing for users to layer on additional levels of privacy and security as needed. One of the most important features within Hyperledger Fabric is Channels, which allows peers to be partitioned off into private groups that have self-contained communication. In practice, this means that a PVH peer and a Kohl's peer can be separated from a Nike peer operating within the same network and have their point-to-point communication kept private from other entities in the ecosystem. Each channel has its own independent blockchain, also known as a side chain, that is exclusive to the participants of that channel. Therefore, absolute privacy can be ensured because only permissioned partners can access the data.

All of the participants were assigned a peer for each supply chain node that they plugged into in the blockchain network. Each peer was responsible for submitting transactions to the network on behalf of their designated end user. For the PVH-Kohl's partner pair, a peer was assigned to each of the DCs that would be contributing live data. For the HK-Macy's partner pair, Herman Kay was assigned a peer to represent their DC and Macy's was assigned two peers, one for their DC and one for their store. Lastly, Nike was assigned two peers, one for their point of encoding and one for their DC. The peers belonging to each partner pair were segregated into separate channels in order to ensure privacy between trade partners. These peers were not only responsible for proposing transactions to the network, but also for maintaining a copy of the distributed ledger, or the chronological record of transactions embedded in the blockchain. In order for new transactions to be added to the blockchain, they must be approved and posted by the peers who preserve and perpetuate the distributed ledger that is native to their blockchain. This mandatory collaboration between peers ensures consistency and accountability between trade partners and it creates a common record of truth that all parties can rely on.

Each partner was assigned a **Peer** for each supply chain node that they plugged into the blockchain network. These **peers** are responsible for submitting transactions to the appropriate **Channels** and maintaining a copy of the **Distributed Ledger**.

The **distributed ledger** is the record of transactions published to the blockchain. Each **peer** in a **channel** holds their own copy of the ledger, and changes to the **distributed ledger** must be performed in unison with the other **peer(s).**





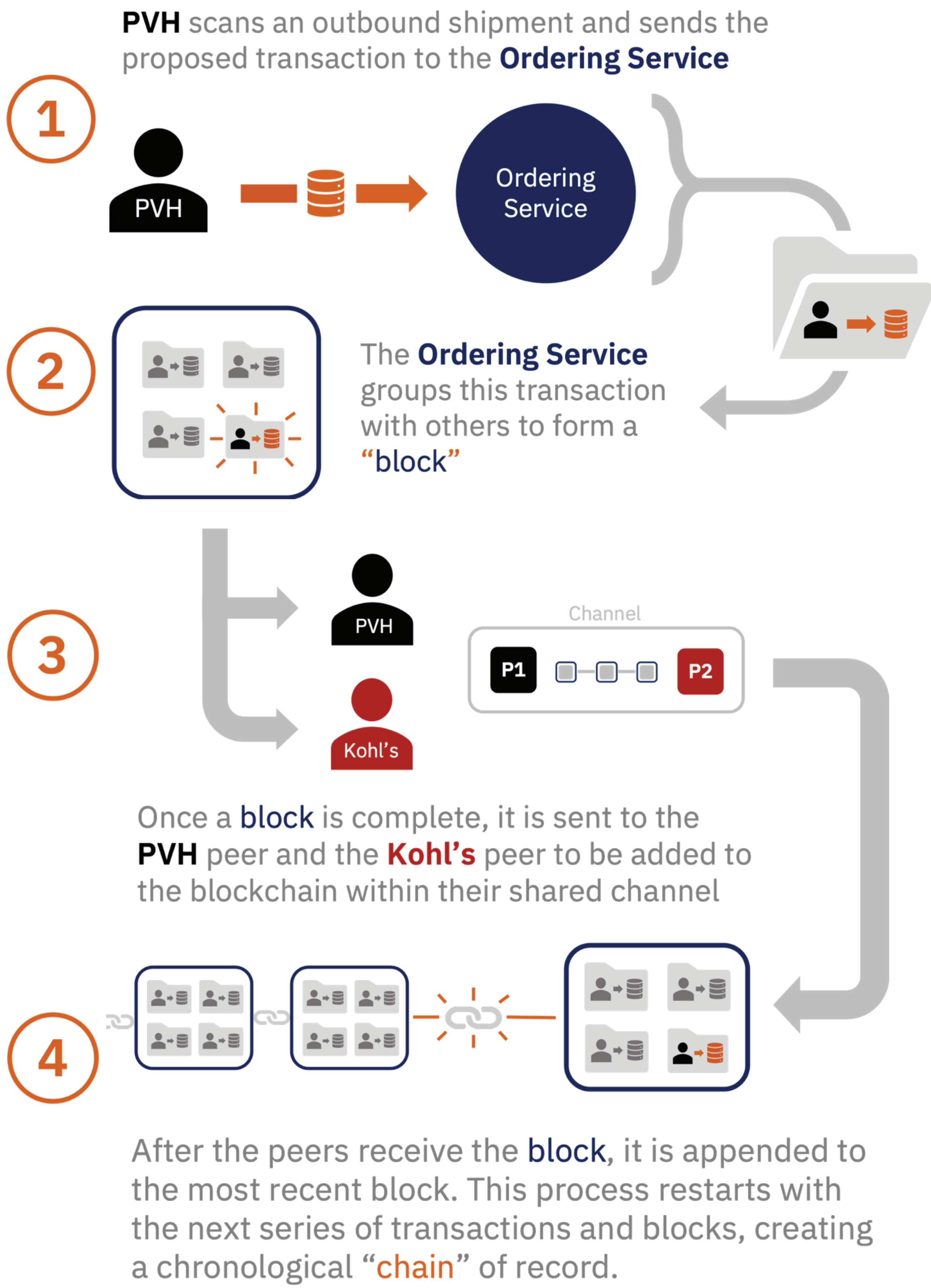
The **Ordering Service** is responsible for receiving transactions from **peers**, organizing them into blocks, and distributing the blocks back to the appropriate **channels**. Once the **peers** within a channel receive a block from the ordering service, they will add it to the blockchain that they jointly manage.

In practice, serialized data associated with a shipment leaving the **HermanKay DC** (P3) would be shared with **Macy's DC** (P4) and **Macy's Store** (P5). In turn, Macy's DC would share serialized shipment information back with **HermanKay** upon receipt, and cycle count data from Macy's Store would also be shared within the channel.

Once the peers were granted proper permissions, the channels that they were part of were connected to the Ordering Service. The ordering service is the heart of the system where transactions proposed by peers are collected and organized into blocks. Once a block is complete, the ordering service redistributes the block to the channel which it belongs and the peers within that channel append the new block to their shared blockchain.

For example, if PVH scans an outbound shipment that is going to Kohl's, the PVH peer would propose a transaction containing the relevant serialized data to be added to the blockchain that the two trade partners share. That transaction would be ingested by the ordering service, where it would be grouped together with additional transactions and made into a block. Once complete, that block would be shared back with the PVH peer and the

Kohl's peer, who would then add the block to their channel-specific chain. This cycle is repeated for all new transactions proposed by either partner. The ordering service itself can be comprised of multiple orderer nodes, but for the course of the proof-of-concept, the CHIP team operated a single orderer node within the ordering service. With these components in place, partner pairs were able to exchange serialized data between supply chain nodes while also ensuring absolute privacy between trade partners.



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ANALYSIS

Once each partner pair integrated all of their serialized data streams into the blockchain solution, the CHIP team activated their channel and enabled transactions to begin flowing through the network. The following sections will detail the commerce that occurred between partner pairs as well as aggregated information for the network as a whole. Please note that the figures reported for each partner pair should not be used to analyze shipment accuracy; the purpose of this proof-of-concept was to identify individual items at multiple steps throughout the supply chain, not to evaluate shipment accuracy or draw conclusions about order integrity. The degree of RFID deployments varied on a case-by-case basis, meaning that some facilities were fully RFID-enabled and others had smaller deployments in specified operational areas. Therefore, the number of items submitted by each supply chain node does not statistically represent the trade relationship between partners. Additionally, the supply chain nodes within each partner pair did not necessarily begin contributing data at the same time, so while most of the data was collected from overlapping time periods, some items were only detected once because only a single supply chain node was active at that time.

The proof-of-concept was also focused on tracking the lifecycle of individual items beginning at the earliest available touchpoint. Although it was technically possible for every item at every juncture to be written to the blockchain, only the first supply chain node within each partner pair was granted permission to "create" new items; subsequent supply chain nodes could only append new transactions to the chain if the serialized data points matched an earlier entry. The primary purpose behind this decision was to prevent unfiltered data from a retailer's DC, which could contain serialized data from multiple brands, from being shared back with the brand they were partnered with for the course of the proof-of-concept. So while the total number of items submitted by each supply chain node is noted, only the items indicated as 'matched' have been uploaded to the blockchain.

Purpose of the Analysis:

- ✓ Share serialized data between trade partners
- ✓ Identify individual items at multiple steps in the supply chain

***Not* the purpose of the Analysis:**

- ✗ Evaluate order accuracy
- ✗ Benchmark RFID systems
- ✗ Statistically represent trade relationship between partners

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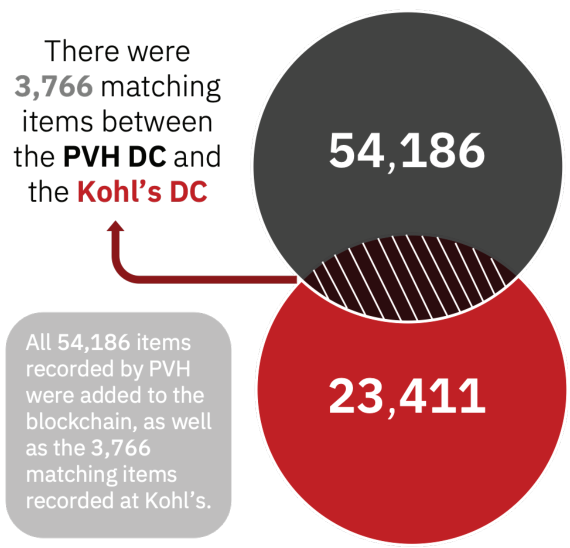
Analysis

PVH-Kohl's Partner Pair

The PVH-Kohl's partner pair provided data from September to December 2019, with PVH contributing outbound data from a DC and Kohl's contributing inbound data from a DC. During the data collection phase of the project, 54,186 individual PVH items were posted to the blockchain, all of which were destined for the Kohl's DC. Kohl's captured 84,958 inbound items at their facility, 23,411 of which were PVH items. Because Kohl's contributed serialized data from multiple suppliers, the only items written to the blockchain by Kohl's were PVH products. It is worth noting that only one receiving line in the Kohl's DC was RFID-enabled, and when combined with the fact that Kohl's contributed data from a smaller timeframe than PVH, the differences between the two figures can be reconciled. Altogether, 3,766 items were detected at both facilities. Each matching item had a two-transaction history: one from the outbound process at PVH and one from receipt at Kohl's.



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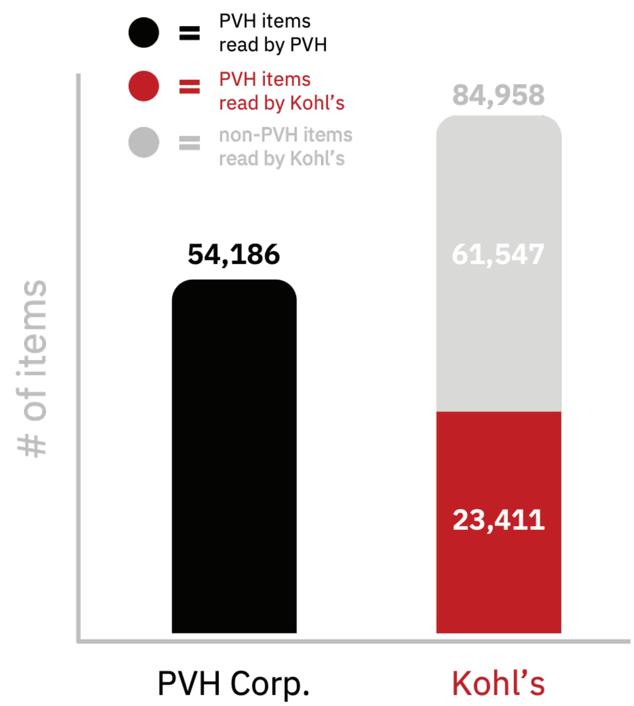

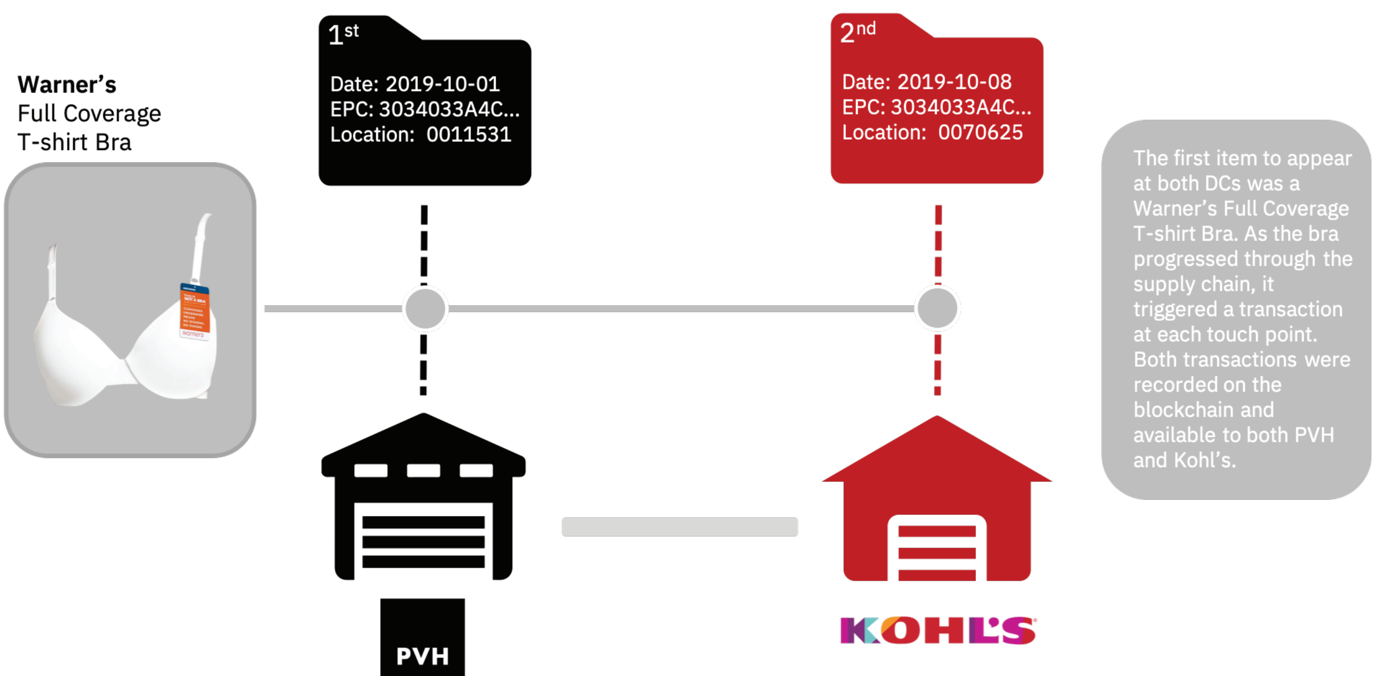

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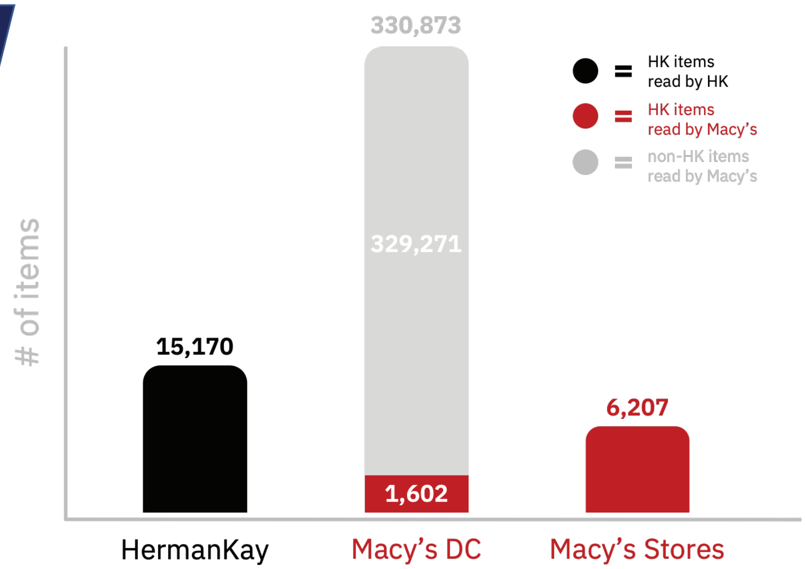
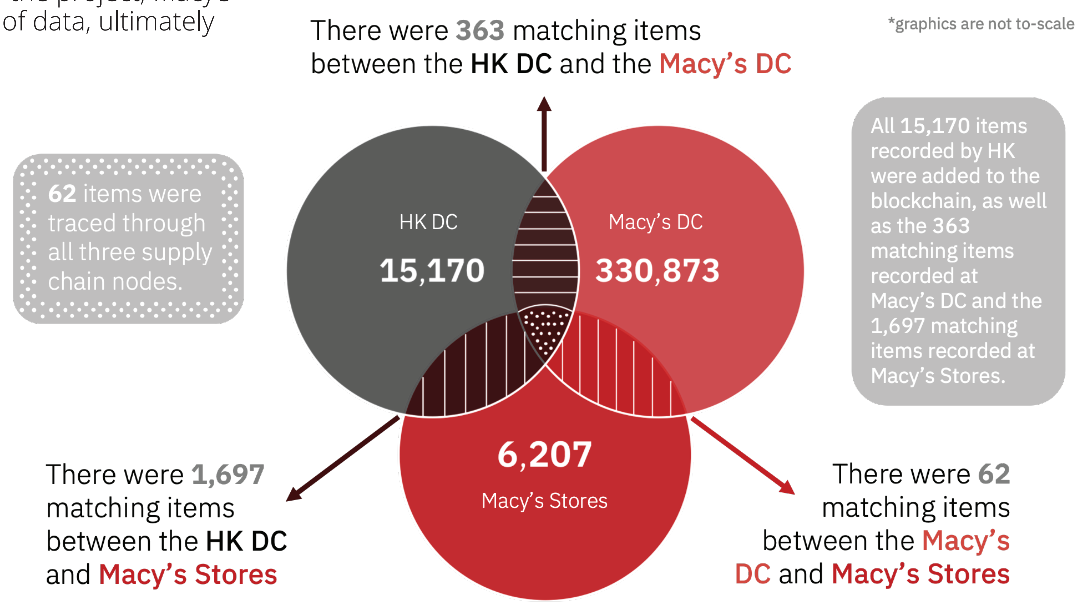
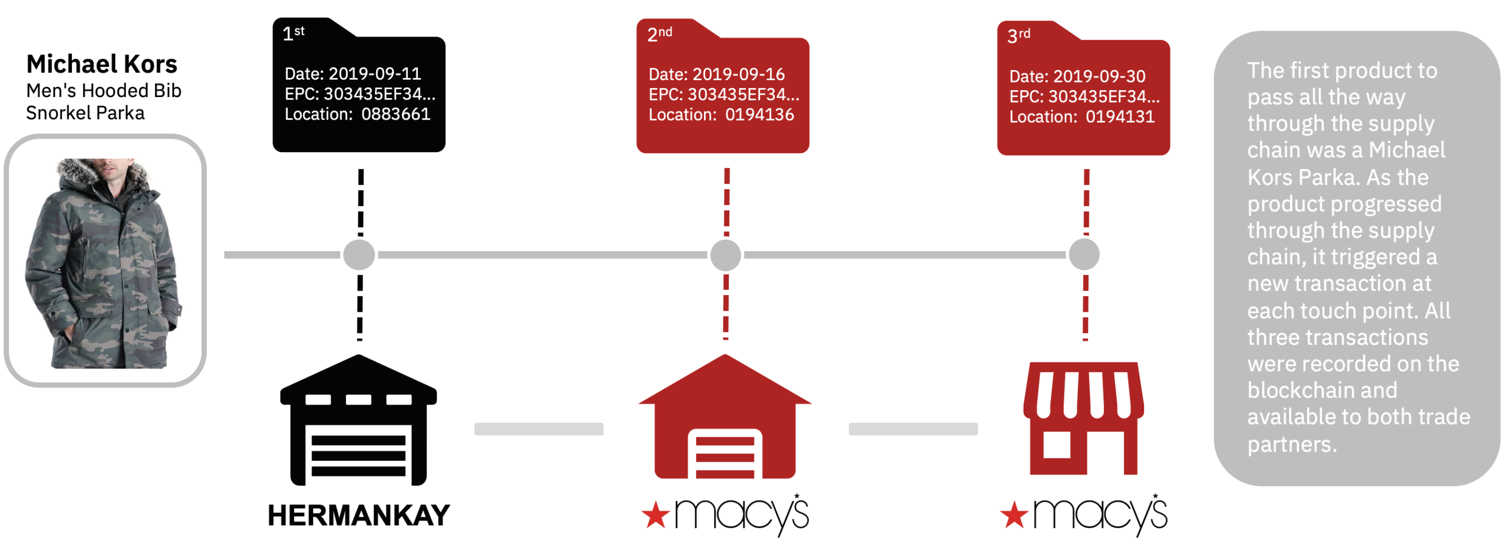
Analysis

HK-Macy's Partner Pair

The HK-Macy's partner pair provided data from April to November of 2019, with HK contributing outbound data from a DC and Macy's contributing inbound data from a DC as well as cycle count data from a store. It is worth noting that HK's entire outbound operation at the DC was RFID-enabled and serialized data was captured for every shipment, whereas the Macy's DC had only a small fraction of receiving lines that were RFID-enabled. Consequently, only a subset of inbound HK shipments were captured. Additionally, cycle count data was filtered to include only HK items in the store. During the data collection phase of this project, HK recorded 15,170 individual items, all of which were written to the blockchain. Of all the supply chain nodes plugging into the project, Macy's DC provided the highest volume of data, ultimately capturing 330,873 items. Of these 330,873 items, 1,602 belonged to HK and 363 of them matched items previously seen at the HK's DC. In Macy's Stores, 6,207 HK items were detected during monthly cycle counts; 62 of those items could be traced through the Macy's DC all the way back to the HK DC, with every item returning three unique transactions for each supply chain node they passed through. Interestingly enough, there were 1,697 matching items between Macy's Stores and the HK DC, which were also written to the blockchain.



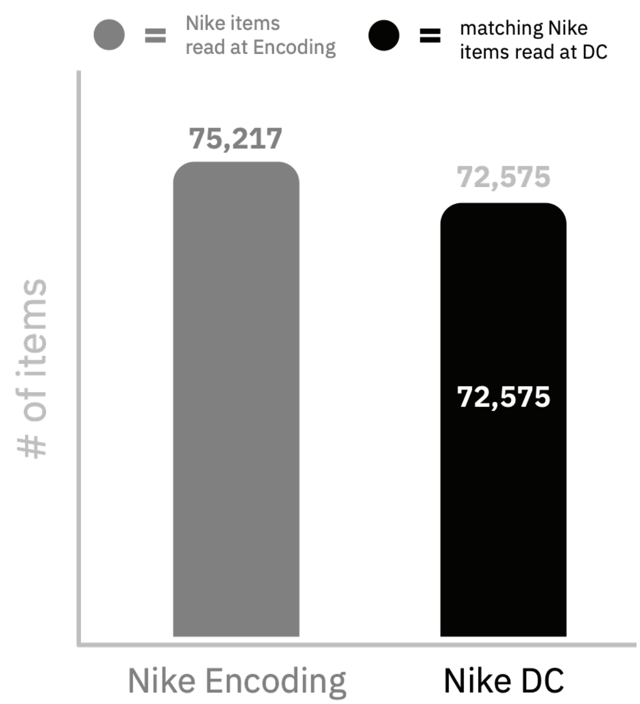


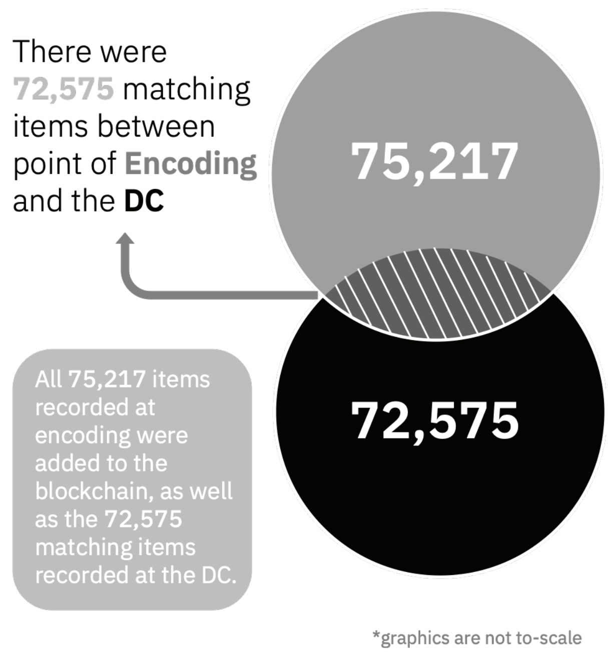


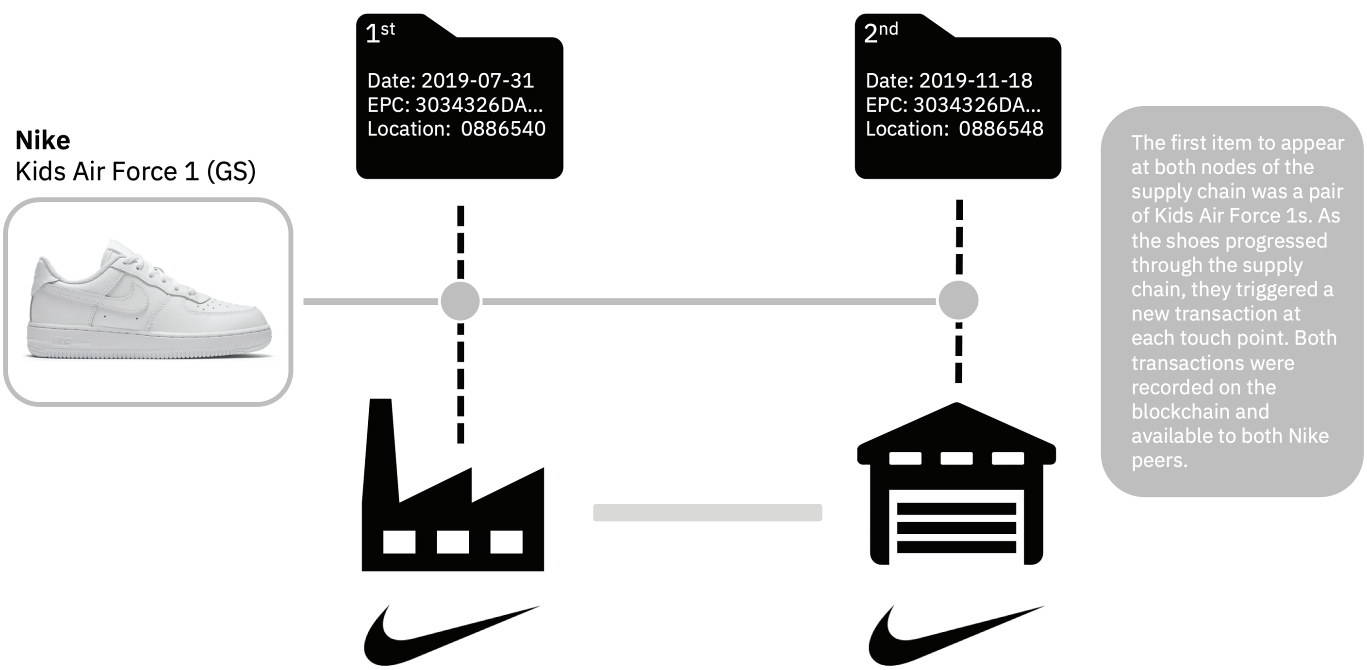
Analysis

Nike Partner Pair

Nike contributed datasets ranging from January 2019 to December 2019 from both the point of encoding and from the DC. Backlogs of encoding data were provided at multiple points in time, with the earliest timestamp being January 3rd. DC data came from a shorter time period between November and December, and these data sets were also provided after-the-fact. A total of 75,217 items were shared from the point of encoding, and 72,575 total items were shared from the DC. Additionally, there were 72,575 matching items between both touch points.







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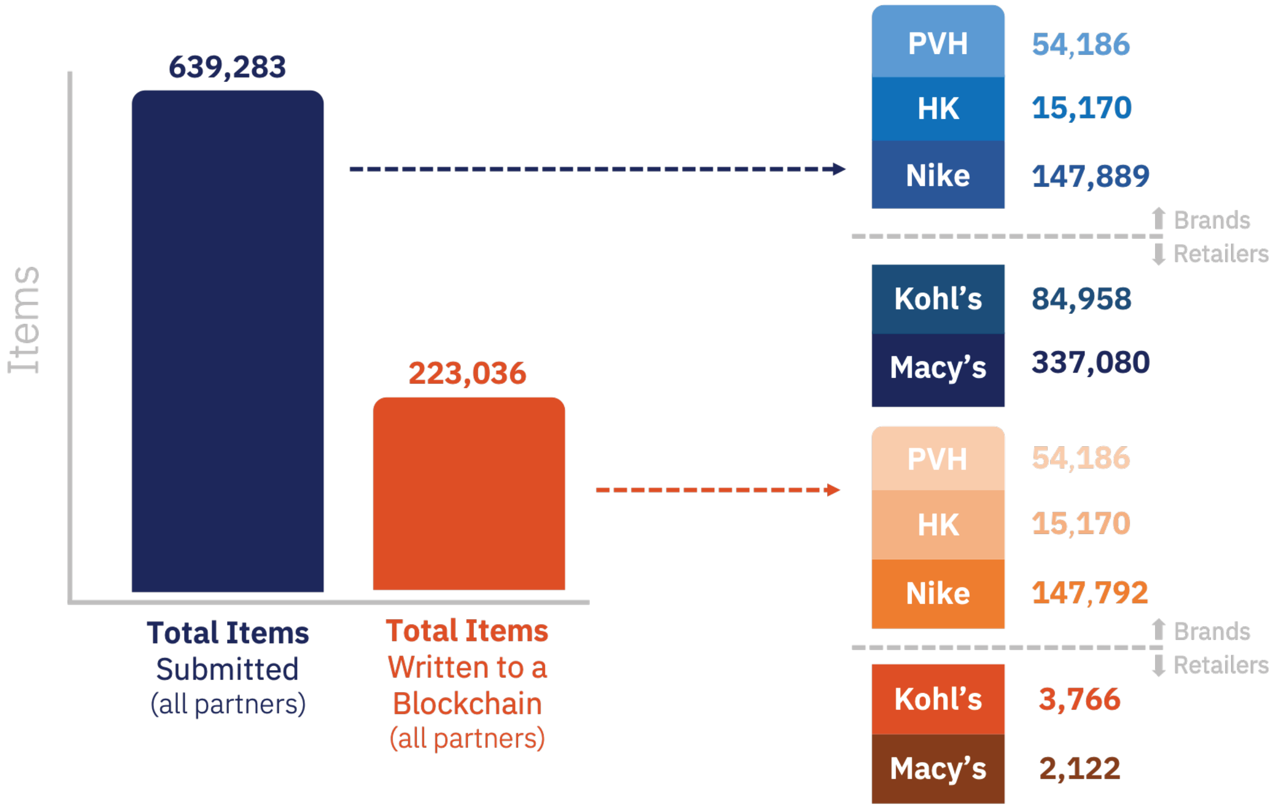
Analysis

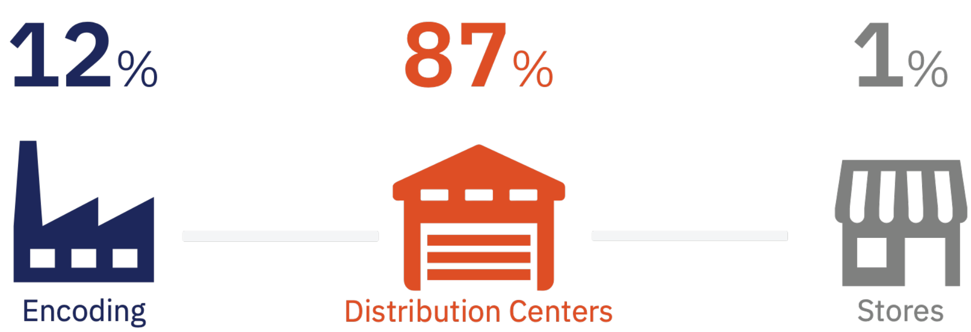
Aggregated Analysis

In total, project partners collectively contributed 639,283 items throughout the course of this project, 223,036 of which were written to a blockchain. The difference between these two totals is due to additional data shared by retailers that included over 400 brands outside the scope of the CHIP Project. For example, Macy's supplied serialized data related to vendors besides HK, but because the network only supported the HK-Macy's trade relationship, only data relevant to HK was written to their blockchain. When broken down by supply chain node, 12% of the data came from a point of encoding, 87% came from DCs, and 1% came from stores.



Analysis

Data Sources broken out by Supply Chain Node



CONCLUSION

Given these results, the CHIP team and project partners were able to conclude that blockchain was a functional solution for serialized data exchange. While there are still many opportunities for improvement, each partner pair was able to record transactions containing serialized data in a common language and share that data with their appropriate trade partners.

OPPORTUNITIES FOR IMPROVEMENT

In terms of the blockchain solution itself, there are several areas in need of improvement. Preliminary testing revealed that transaction processing speeds within the network were significantly slower than originally expected at 0.33 transactions per second (tps). At this speed, the network would not be able to support the volume of data expected from the partners participating in the project. However, after some optimization, transaction throughput increased over 6,500% to 22 tps, permitting the network to process over 1.9 million item-level transactions per day. While this level of performance was acceptable for this proof-of-concept, a network looking to support a larger number of partners and inputs would need further optimization. Production-grade instances of Hyperledger Fabric are capable of handling thousands of transactions a second, so additional optimization would be required in order for this solution to compete with the currently available solution.

Additionally, the CHIP team configured and controlled the different aspects of the blockchain solution throughout the course of this project, including the peers belonging to each partner and the pathways for others to interact with the network. Although this degree of oversight was required in order to design, construct, and administer the blockchain network for this proof-of-concept, the ideal blockchain solution would not be nearly as centralized. In the case of a more mature, intellectually pure project, it would be preferable for each partner to support their own peers and for the overall administration of the network to be divided amongst multiple parties. By distributing responsibility and democratizing governance, a network like this would be able to reap the broader benefits that blockchain offers, such as decentralization and enhanced fault tolerance.

No final determinations have been made about the future of the current CHIP network, but regardless of the solution selected for the next phase of the initiative, every participant (i.e., end users and solution providers) will be expected to take on a more significant, self-sufficient role within the blockchain ecosystem.

NEXT STEPS

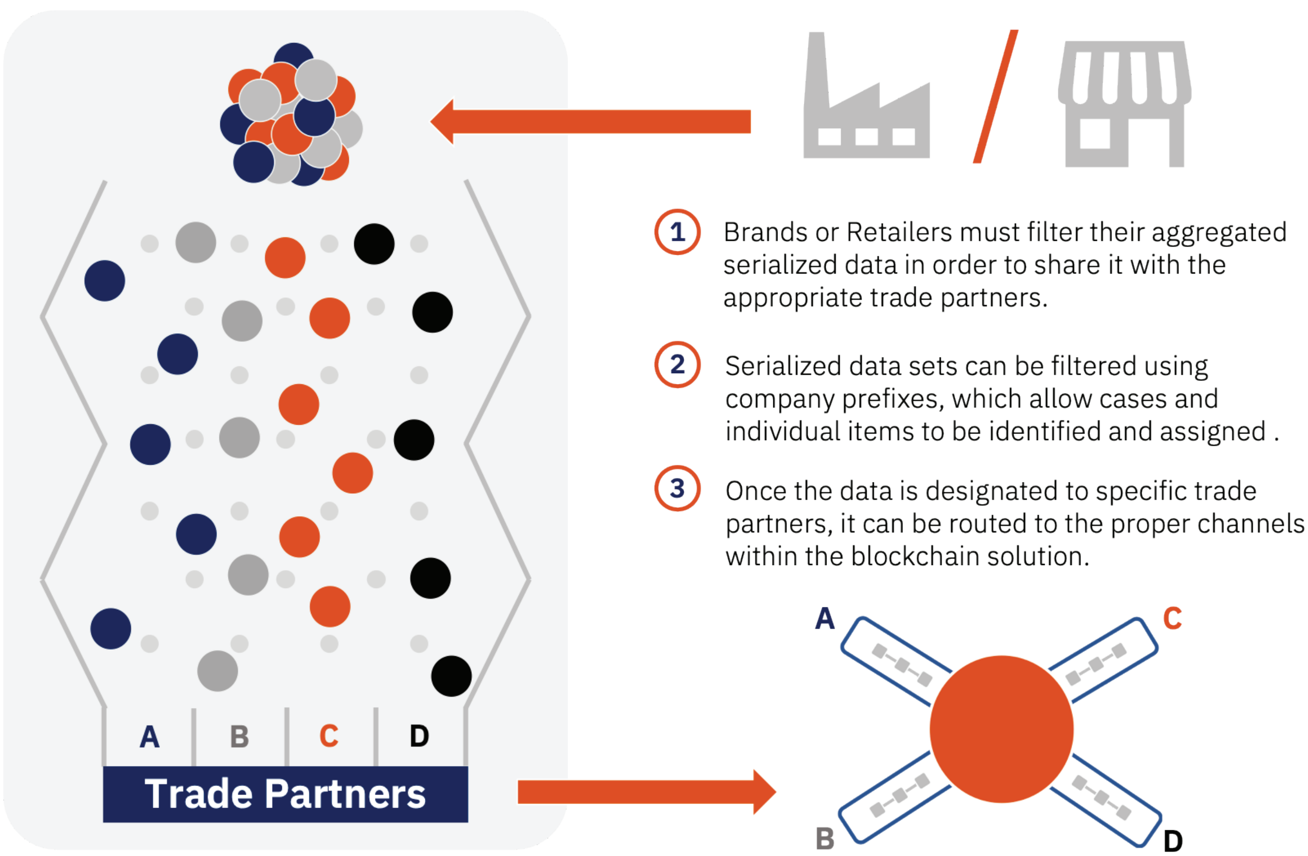
While the proof-of-concept proved the effectiveness of a blockchain solution for serialized data exchange, the pilot will seek to determine the business value implications by using the blockchain-based, serialized-data solution to eliminate claims and chargebacks that occur between brands and retailers. By utilizing test and control methodology, the pilot study will explore the financial implications of uniting serialized data capture systems and creating a common platform for data exchange. Stricter adherence to data standards is expected from participating partners and process changes within physical facilities are also expected. Although a definite date has not been determined for the start of the pilot, end users and solution providers are expected to take on more responsibility when it comes to managing and maintaining the blockchain network. Given the ever-increasing volume of serialized data in the supply chain and the continued maturation of blockchain as a technology, the CHIP initiative is well positioned to prove out the business value behind both of these emergent technologies.

RECOMMENDATIONS FOR BLOCKCHAIN IN SUPPLY CHAIN

Trade partners who wish to deploy a blockchain solution in their supply chains must consider several steps. First and foremost, each organization must take into account the amount of serialized data in their supply chain. Whether it is the commissioning of an item at its inception or its final sale at the store, every touch point with the capacity to capture item-level data has a compounding effect on the value of a blockchain solution. Consider a metaphor using photography terms. Each supply chain touchpoint integrated into the blockchain is like a camera that has the ability to take a photo of an item. When a photo is taken of an item at a certain place and point in time, it is added to an album featuring that particular product. An initial photo is taken at the point of manufacturing, and additional snapshots will be taken as the product passes from one supply chain node to the next. As new photos are added to the album, an item's story can be pieced together revealing its ultimate path throughout the supply chain. Therefore, it is ideal to capture and record as many photos as possible of each item, especially if the goal is to enhance visibility and traceability throughout the supply chain. While additional infrastructure may be necessary to satisfy the requirements of the blo ckchain solution at hand, organizations that have already deployed serialized data infrastructure stand to benefit from prior investment.

Another key consideration when it comes to evaluating serialized data systems is overall data quality. In order to reap the benefits of a blockchain network, it is essential to establish a level of baseline accuracy for the data that will form the foundation of the solution. If data does not reflect the flow of physical goods, then it does not matter whether or not that data is on the blockchain; "garbage in, garbage out" as the axiom goes. Therefore, a threshold for accuracy must be defined and enforced along with regular reviews to ensure consistent, quality data.

Once all relevant information systems have been identified, a common language must be established within the blockchain network, especially if there will be communication across organizational borders. Familiarity with EPCIS and GS1's Core Business Vocabulary is also imperative, as both are used in conjunction to establish a common language amongst trade partners. Standardization of serialized systems can be accomplished in a variety of ways, with the implementation efforts resting on either the



end user or their solution provider. In theory, this process could also be performed on the blockchain with the use of smart contracts, but because of the inherent value of supply-chain–wide standardization, organizations are better off in the long term standardizing their serialized data systems before blockchain enters the equation. Once the relevant data streams are standardized, it is important for each stakeholder to filter the data for the appropriate stakeholders. Assuming private channels are established between trade partners, it is imperative that data streams are allocated accurately to the proper participants. In practice, however, this is a non-trivial task. Brands often ship products to dozens of retailers and have their own suppliers upstream, and an analysis of retailer data revealed 508 combined vendors between both Macy's and Kohl's. One way to filter for these partners would be to use the company prefixes embedded in serialized data streams, allowing an organization to identify cases or items by company and assign them to the proper channels within the blockchain network. As long as the company prefixes are kept up-to-date, each company would have the capacity to direct data to the correct trade partners.

Lastly, stakeholders must integrate their standardized systems into the blockchain itself, where all relevant transactions will be broadcasted, approved, and posted to the distributed ledger. The details of this step are non-trivial and largely dependent on the blockchain solution chosen for the use case. Partner priorities tend to guide the selection process, and since privacy and security are common concerns for business-to-business use cases, private and permissioned blockchains like Hyperledger Fabric, Hyperledger Sawtooth, and Corda tend to be the most fitting frameworks. Once a network is constructed and the integration step is completed, the physical supply network is modeled digitally within a blockchain network. The unique digital identity found for each product is captured at each touch point as it moves throughout the supply chain and the standards in place ensure discernable data is passed from one stakeholder to another. The complexity of the integration step should not be underestimated, because it truly takes a village to tie together the disparate data streams that exist in any given value chain.

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ABOUT THE RFID LAB

The Auburn University RFID Lab is research center that focuses on the business case and technical implementation of emerging technologies in the retail, aerospace, and automotive industries. Since its inception in 2005, the RFID Lab has conducted a series of seminal business value studies that have led to the adoption of RFID and other IoT technologies throughout multiple industries. Sponsors of the RFID Lab include: Amazon, Avery Dennison, Boeing, Checkpoint, Delta, FedEx, GS1 US, Intel, Mojix, Nike, NXP, Smartrac, SML, Target, Home Depot, Tyco, VF Corp, Walmart, and Zebra Technologies.

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