AI, IoT, Blockchain, and Robotics for End-to-End Supply Chain Planning, Monitoring, and Management

By Jim Davis and Eric Lam, Ph.D.

Smart Supply Chain Technologies, Ltd., a.k.a. S2CT, views the end-to-end supply chain as extending from the commercial source of a product to in-the-hands of a consumer. This paper will utilize S2CT's previously published white paper "Retail Grocery Store Logistics and Inventory Management" as the framework for this expanded comprehensive paper. This paper is intended to reflect a futuristic but practical vision of the "Digital Supply Chain". The future Digital Supply Chain will be driven by "Cloud" and "Edge" Artificial Intelligence (AI), ultra-cost-effective and reliable connected AI enhanced IoT devices, secure Blockchain based Trade-Data-Sharing and Task-Specific Autonomous Robotics. These technologies and devices will deliver "just-in-time" inventory management and bring unimaginable inventory monitoring and handling efficiencies to those companies that embrace them.

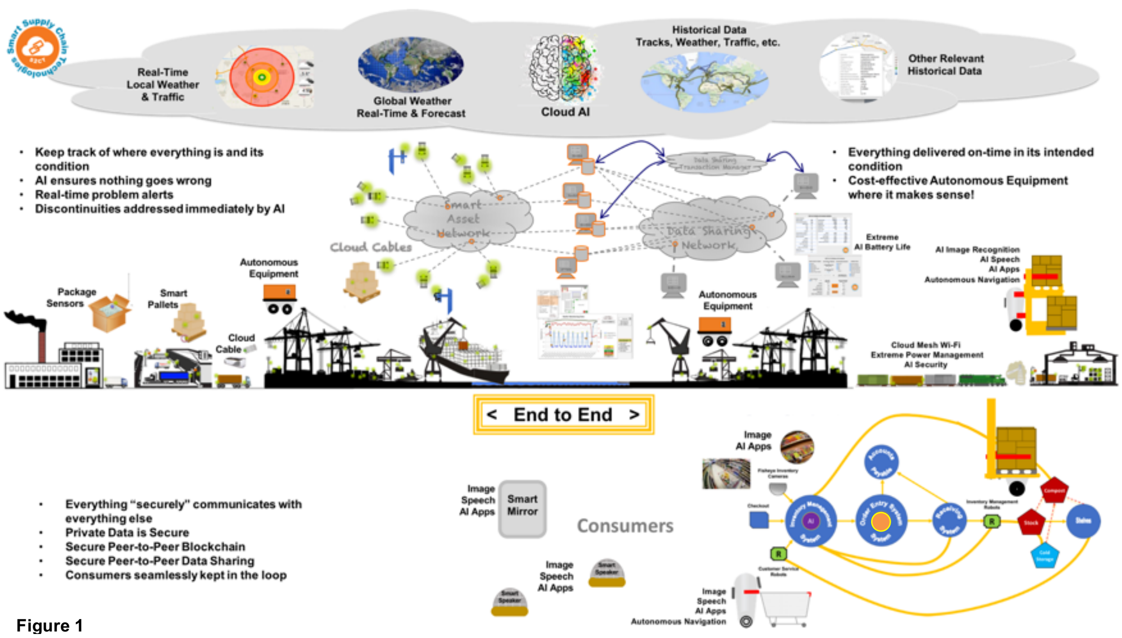


Figure 1

Since AI is a central theme for S2CT [(1)] this paper we'll begin with a short high-level AI tutorial for readers that may not be deeply versed or confused by what AI is. AI is a term used to describe a myriad of mathematical and software techniques used to assist computers to solve complex problems. This paper will use the term AI to refer to Neural Networks and AI Driven Algorithms that rely on historical data posed against real-time data to perform tasks.

First let me acknowledge 3blue1brown [(*)], by Grant Sanderson and "Neural Networks and Deep Learning", by Michael A. Nielsen, as excellent resources for understanding neural networks and the mathematics behind them. Much of the material here was derived and even cloned from 3blue1brown video series. Those videos and this paper reflect what's now considered "early" neural network concepts and don't try to describe the current state-of-the-art. The intent here is to describe neural networks to the extent necessary for readers to appreciate their complexities, awesome power and limitations. S2CT offers to its clients AI and supply chain consulting to its clients and a number of Python programs for its AI projects and examples.

An easy way to appreciate neural networks, as well as to illustrate the kinds of problems they are best suited for, is to examine how a neural network distinguishes one handwritten integer from another. The neural network pictured in figure 2 illustrates a classic neural network for solving this problem.

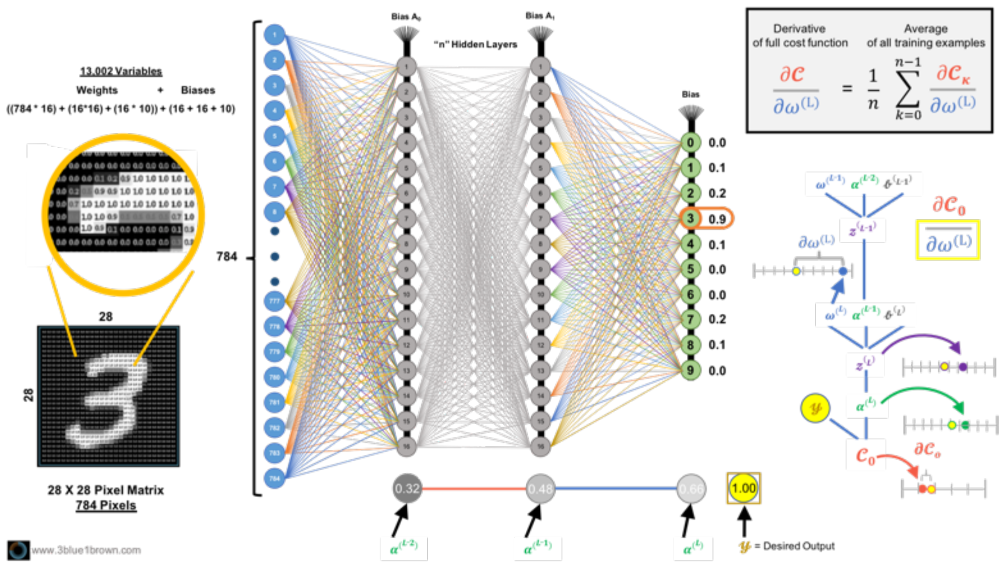


Figure 2

The first step in developing the neural network is to describe its structure. This begins by defining a comprehensive, reliable and persistent method to characterize the input data that can unambiguously drive the neural network's "input-layer", the blue circles in figure 2. This may seem obvious and straightforward but it's not and it's critical! This should become apparent as our neural network description develops. In this example the input-structure is a "fixed" dot-matrix, 28 dots by 28 dots, that represent pixels on a display. When a handwritten integer is displayed, the pixels, dots, vary in intensity from "bright" where the handwritten integer is full-on to "less-bright" at the integer's edges to "dark" for pixels that are not involved in the integer's display. These pixel variations can be represented with values between "0" for "dark" and "1" for "bright" with values like 0.8 and 0.7 at a character's edges. Each different handwritten '3' that might be displayed will result in different values for many of the pixels in the matrix. This translates to 28 pixels x 28 pixels or 784 inputs, varying between "0" and "1", for the neural network's input-layer to pass to its hidden-layers, the gray circles in figure 2.

The neural network's hidden-layers are where all the magic happens! Unlike traditional algorithmic software where every element is designed and built to carry out a specific well define task, hidden-layer "neurons" are not. What the hidden-layers and their neurons do is not necessarily directly revealed to the neural network's developer. Even the number of hidden-layers is somewhat arbitrary as well as how many "neurons" are in each. This is the magic and beauty of neural networks, "hidden-layers" are recursively "trained" to properly discern different input-data to drive the neural network’s “output-layer” to yield a proper conclusion. Ideally, any handwritten ‘3’ will drive the ‘3’ output-layer “neuron” to be the “brightest”, ‘1’ or near ‘1’, and all other “output-layer” neurons to be less “bright”, and therefore less than ‘1’.

Training a neural network utilizes straightforward, albeit beautiful, mathematics. Each neuron in the input-layer has an activation level, between ‘0’ and ‘1’, related to its associated pixel and the displayed integer. Each connection between each input-layer neuron and each neuron in the neural network’s first hidden-layer is assigned a “weight”, initially randomly. The “activation” of each hidden-layer neuron is the “weighted-sum” of all the activations from each of its connections to the previous layer, in this case the “input-layer”, $x = (\omega_1\alpha_1 + \omega_2\alpha_2 + \omega_{...})$. Squishification, sigmoid or some other method, forces this “weighted-activation” between ‘0’ and ‘1’, $\sigma(\omega_1\alpha_1 + \omega_2\alpha_2 + \omega ...)$ or $\sigma(x) = 1/(1 + e^{-x})$. A method used to skew a neuron’s weighted-sum-activation is to introduce a “bias” into the weighted-sum, before squishification, to modify the weighted-sum’s impact, $x = (\omega_1\alpha_1 + \omega_2\alpha_2 + \omega_{...} + \mathscr{b})$. The bias typically reduces the “weighted-sum” by its magnitude and therefore reduces the squishified neuron activation.

This process continues from “hidden-layer” to “hidden-layer” to “output-layer” propagating activation levels and using independent neuron bias levels. This is pictured in figure 1 with the 784 neurons in the “input-layer” receiving activations from the input-data, the 16 neurons in the first “hidden-layer” receiving activations from the 768 neurons in the “input-layer”, the 16 neurons in the second “hidden-layer” receiving activations from the 16 neurons in the first “hidden-layer”, the 10 neurons in the “output-layer” receiving activations from the 16 neurons in the second “hidden-layer”. Additionally, each neuron in the “hidden-layers” and “output-layer” have independent neuron biases. This translates into 13,002 variables or knobs that can be adjusted to “train” the neural network to correctly identify every handwritten integer in the “training-data”, tens if not hundreds of thousands of handwritten and categorized integers. Data is “king” for AI Neural Networks.

The magic of the neural network is the ability to mathematically manipulate these 13,002 variables such that the resulting “static” neural network successfully recognizes each of the handwritten integers in the “training-data” and beyond that, recognizes new handwritten integer that it has never seen before. This is what is meant by saying a neural network “learns”. This is as beautiful as the calculus that does it and not dissimilar in how calculus does what it does. Think about how calculus determines the slope of a “point” in two-dimensional space.

This “learning” process begins by showing the neural network, initially using random “hidden-layer” neuron activations and biases”, the 784 activations levels for each handwritten-integer in the training-data and observing the output-activations for the neurons in the output-layer. This “observation” is facilitated by a mathematical expression that calculates a “$\mathcal{C}$ost” for each of the handwritten-integers in the training-data presented to the neural networks input-layer. That is, expressing the difference between the activation that was desired for each output-layer neuron and the actual results with a particular set of weights and biases. This is illustrated in figure 3. Calculating the sum of the squares of the differences between the desired output-layer neuron activation levels and the resulting neuron

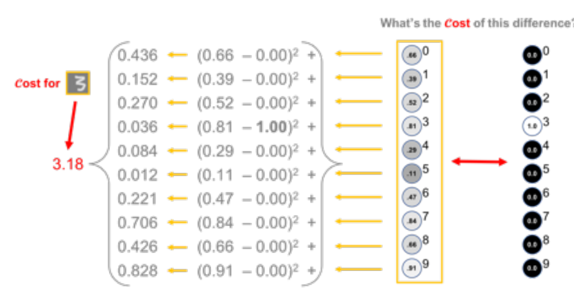


Figure 3

activation levels from the training-data yields a "𝒞ost" for each test. The lower the "𝒞ost" the better the neural network is at recognizing the specific handwritten-integer in the training-data. The total of the "𝒞ost" for each handwritten-integer in the training data is a quantitative measure of how well the neural network will ultimately perform overall.

Finding the "optimal" set of weights and biases, the minimum "𝒞ost" that can be arrived at over the full range of the training-data, is accomplished by recursively manipulating the 13,002 weights and biases over as many handwritten-integer test cases as possible. The MNIST Database (2) has approximately 60,000 categorized handwritten-integers written by 500 writers as of the date this paper was written.

The optimal weights and biases for each output neuron is found by using a technique called "Backpropagation". Backpropagation that looks back from each neural network layer, output-layer looking back at the second "hidden-layer" in our figure 2 example, to determine the activation weights and bias values that impact each neuron in the layer of interest. The resulting x-y plots or 3D contour plots are analyzed to find their local minima using calculus and gradient descent and Monte Carlo techniques like simulated annealing to help ensure that you find the real local minima. Ultimately the objective is to find "the" set of neuron connection weights and neuron biases that yields the "lowest" aggregate "𝒞ost" possible. Once this is achieved the neural network, subject to its structure, should be able to recognize all of the handwritten-integers in the training data with 99.79% (3) accuracy, state-of-the-art circa. 2017.

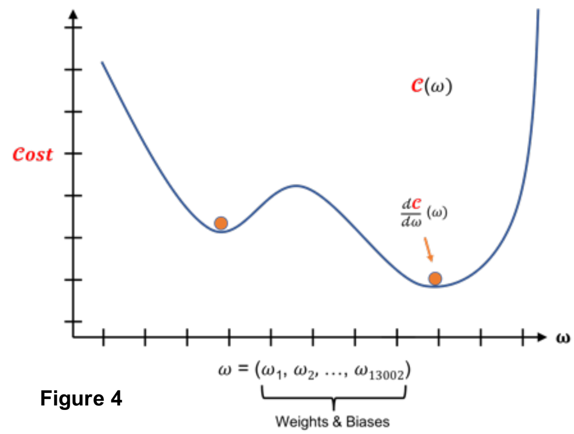


Figure 4

A few key points: training a neural network is compute intensive. Having the neural network evaluate a single set of input data like a single handwritten integer is not compute intensive. If the training input-data contained all possible conditions for the target input-data, then the neural network could approach 99.9% accuracy over all possible related input-data.

The second type of AI that S2CT designs and has deployed is what we call AI Driven Algorithms. These are traditional programs that use and rely on historical data insights, in some cases neural networks, to perform complicated tasks. One example of an AI Driven Algorithm Program is one that accurately predicts the geospatial position of a cargo, a box of electronic parts for example, as it makes its way from a distribution center to a factory through an intermodal supply chain route. S2CT's "route" neural network model employs a Bayesian inference component that updates the probability for its geospatial positions as more real-time evidence or data becomes available. The Distributor, the Logistics Company, contracted intermodal carriers, other contracted data sources, and the factory collaborate to provide both "real-time" and historical data (4). More than one of these supply chain partners will use this historical data to "train" their private neural networks for their parochial interest as well as to support their collaborations. The Logistics Company's neural network predicts the cargo's continuous geospatial position and incremental ETAs, Estimated-Time-of-Arrival, along the intermodal route using its historical data trained neural network and real-time data from each of the supply chain partners. Tracking of a cargo moving along such an intermodal supply chain route by truck, train, vessel and air, has been demonstrated to be better than 96% accurate in terms of geospatial position and better than 99.9% for ETAs.

A second S2CT example of an AI Driven Algorithm Program, albeit quite different in structure and task, can be found in S2CT's IoT AI Battery Life Analyzer, elements of which have been deployed in the Cloud as well as integrated into IoT devices in the field. The Analyzer [5], pictured in figure 5, uses technical data and an S2CT Standard Asset Monitoring IoT Device Model to analyze the estimated battery life of an IoT Asset Monitoring Device. The S2CT Basic Analyzer allows the user to evaluate the number and chemistries of batteries that might be installed in a device, its communications capabilities, its communications rates, and how AI Data impacts the device's battery-life. The Analyzer utilizes a hybrid neural network structure, pictured in figure 6, to generate a "Degree of AI" factor to be used with the other selected parameters to estimate the device's battery life. The final Degree of AI reflects the availability of all of the selected AI Data types and their impacts on each other. For example, indicating that both Private Data and Historical Data are available increases the contributions of both on the final Degree of AI.

Figure 5

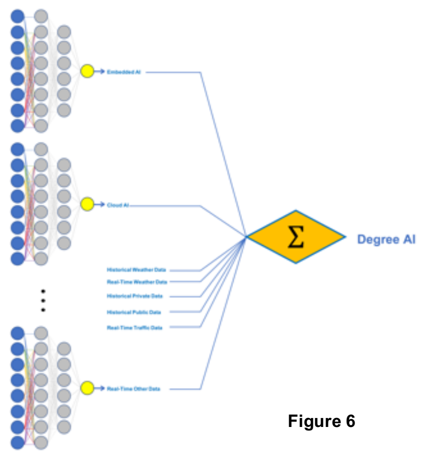


Figure 6

Much of this same software, including the neural networks, is also integrated in battery operated supply chain IoT devices to actually extend their battery lives in the field. Those algorithms, using low-overhead fast neural networks that were "trained" in the cloud can quickly determine if using battery energy to execute a route-task is worth the energy cost. For example, a Logistics Company trains a "route" neural network, in the cloud, that predicts the route that a cargo will travel through a particular supply chain and the communications capabilities known to be available along it. The IoT device's "trained" route neural network is downloaded to the IoT device as its journey begins and is updated throughout the journey as required. The IoT device now has the integrated capability to determine if it's on the predicted route or not. If the software determines that the IoT device is where it was predicted to be, and that acquiring GPS is particularly difficult at that location, the device skips the normally schedule GPS acquisition cycle to save battery energy. In addition, if there are no unsent-critical-alerts waiting to be sent, the device skips its scheduled telecom-GPRS communications cycle as well to conserve even more battery power. Analytics and live deployments of this AI Battery Life Management Software indicate that more than 80% of the normally consumed battery power can "typically" be saved using these techniques, extending the devices battery life by 5 times.

AI Inventory Demand Planning

As previously stated, S2CT views the end-to-end supply chain as extending from the commercial source of a product, the supplier, to when it arrives in-the-hands of a consumer. For S2CT this begins with inventory Demand Planning.

Imagine a local grocery store, having an objective of maximizing customer satisfaction and thereby store patronage and loyalty, maximizing revenues and maximizing profits without cutting staff, that:

- offers every item, at the local store, that its customer base wants

- offers lowest-prices driven by the efficiencies of supply chain monitoring and management
- offers shopping-list synchronization with Personal Assistants, with updates and alerts
  - offers “trusted” opt-in multi-level personal-data security
- always has your items on their shelves
- never has products with “expired” dates on its shelves
- provides real-time in-store product comparisons in terms of:
  - product place-of-origin, “normalized” unit cost, in-store and online Sale information, in-store product shelf location with shelf and stockroom inventory status
  - real-time backroom stock request if necessary, stock clerks find you in the store or at the checkout register
  - local competitor published prices, ingredients, dietary data and expiration date.
- delivers groceries that aren’t available during your store visit to your home
  - Informs you of any added fees
  - Informs you when the out-of-stock item will be available in the store for pickup
- streamlines points-of-aggravation like Deli and Bakery with digital queues
  - Digital Orders
  - Order-ready digital alerts

All of this can be accomplished today with secure point-to-point data-communications across the supply chain using Cloud and “Edge” AI, cost-effective connected AI-driven IoT devices, Blockchain Technology and Task-Specific Autonomous Robotics.

Using the S2CT “Retail Grocery Store Logistics and Inventory Management” white paper as the backdrop, this journey begins with AI-driven Inventory Demand Planning. This is a complex problem but in many ways the grocery store is the perfect application for neural networks with vast amounts of historical data for every level of its enterprise. Noting again that data is critical for neural network success and that the data must be comprehensive, reliable, persistent and unambiguously to drive the neural network’s “input-layer”. This means that more store-level forensic data is required reflecting extrinsic impacts on optimal store inventories like holidays, competitor promotions, etc.

There are already traditional enterprise solutions from Amazon, IBM, SAP (*), and others for demand forecasting but these are enterprise solutions. They forecast demand at the enterprise level and push those forecast down to regions and local stores. S2CT is experimenting with a reverse model that is anchored in forecasting demand for each local-store before rolling them up to regions and then regions to the enterprise.

S2CT’s current approach is using a hybrid recursive neural network model in which the Enterprise provides input data to the Regions which in turn provide input data to the Stores, pictured in figure 7. Each neural network uses its specific historical data, specific real-time “extrinsic-relevant-data” and algorithms to recursively modify its input-levels until an equilibrium across the entire system is achieved.

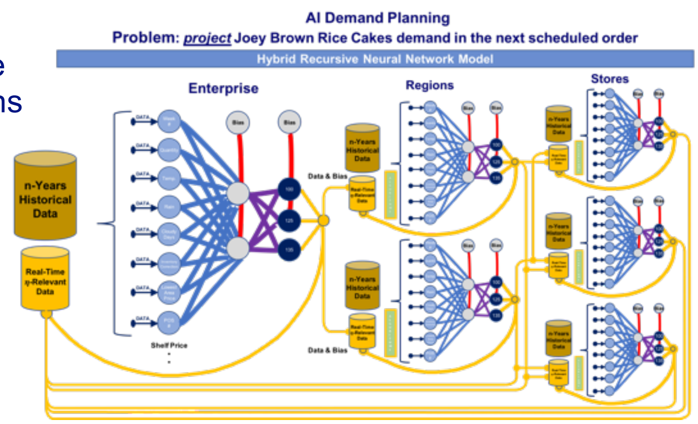


Figure 7

Key to the success of this approach is the definition and availability of both historical and real-time “extrinsic-relevant-data”. This data reflects extrinsic circumstances and events that logically impact the sales of various merchandise in local-stores, like period-weather conditions, local community events, local-store sales of competing products, etc.

The idea is simple, use a top-down / bottoms-up approach to determine the “optimal” inventory demand for every store in every region across an enterprise, week-by-week or even daily. The Enterprise sets business objectives and goals for itself and related supporting business objectives and goals for each of its regions. This might be a goal of maximizing Enterprise revenue which might sacrifice profits by allowing increased shrinkage to ensure that there is more than enough product on a store’s shelves. This might be the reverse, maximize profit which suggest minimizing shrinkage which mean less of a particular product on the shelf. Nothing prevents these objectives to be different region to region or store to store. These objectives and goals are reflected in “biases” hierarchically distributed through the recursive neural networks pictured in figure 7.

The Enterprise, based on its overall business objectives and goals, using enterprise historical sales data and relevant enterprise extrinsic data, sets the business objective, goals and initial inventory demand for every product for each of its regions.

The Region, based on its Enterprise set business objectives and goals, using region historical sales data and relevant region extrinsic data, sets the business objective, goals and initial inventory demand for every product for each of the stores in its purview.

The Store, based on its Regional set business objectives and goals, using store historical sales data and relevant store extrinsic data, sets the initial inventory demand for every product in its forecast.

Each Store communicates its inventory demand back to its Region where the Regional AI reoptimizes the business objectives and goals for the store and communicates new objectives and goals back to the store if required. This feedback loop terminates when Region results become stabilized, akin to arriving at a local-minima.

This process is similarly executed between the Enterprise and its Regions until an overall optimal result is arrived at and the Inventory demand across the Enterprise is set and committed.

S2CT is developing this AI Recursive Neural Network System and Concept and expects to publish a future Research Paper describing its details, evolution and results, both simulated and actual with authorization from our collaborating clients.

Finally, the only point to forecasting inventory demand accurately is to execute its proper delivery to a consumer. This means monitoring and managing each product’s every movement through the end-to-end supply chain to its final consumer destination.

The next section of this paper will describe how AI, the Cloud, IoT, Blockchain and Autonomous Robotics ensure that happens.

Retail Grocery Store Inventory Management

By Jim Davis, Eric Lam, Ph.D., Alejandro Cano, and Derek Fong

The future of retail grocery stores will be driven by “Smart” Logistics and Inventory Management. The exploitation of Artificial Intelligence, Big Data, and for Inventory Demand Planning, Monitoring, and Management, and continuously vigilant Robotics will separate those stores that succeed from those that fall by the way side. Witness the onslaught of Amazon and Whole Foods, and Walmart, Google, and Uber [*] changing the industry's landscape overnight with just-in-time inventories, until recently unimagined customer conveniences, and virtually eliminating store shrinkage. The technologies underlying and driving these disruptive changes are widely available to everyone today. It only remains to be seen which companies embrace them, survive, and prosper and which don't.

Retail Grocery "Smart" Logistics and Inventory Management Technologies

Retail grocery store just-in-time smart logistics and inventory management begin with each store's Inventory Management System driven by AI and historical and real-time data. This journey begins when the store's Inventory Management System uses AI to forecast inventory demand and places orders. The insights offered in this paper reflect months of hands-on research with a major U.S. grocery store chain, coupled with broad AI research. Much of what is described in this paper is directly applicable to online and concierge shopping, with customer pickup, but those shopping experiences aren't addressed directly.

Our research shows that just-in-time, cloud-assisted, AI Inventory Management can be easily and cost-effectively implemented in any grocery store. That research further shows that the underlying technologies, Cloud, Artificial Intelligence, fisheye cameras coupled with AI image recognition, Inventory Management Robotics, and Customer Service Robotics, can be incrementally deployed with virtually no disruption to the store's legacy systems, software or workflows [6]. Robotics may seem fanciful but our research clearly shows that cost-effective, task specific robots, will be indispensable to achieving the "operational-results" that future grocery stores will require.

Transparent AI components simply provide data to the store's legacy software that then uses it, in conjunction with other data in the store's system and in the cloud, for real-time analysis and decision making. The AI components might not even be installed or running on the store's computing platform, rather it might be running in the cloud on an enterprise server or even as a service from a solution provider. Finally, our research and its analysis clearly show that reduction of shrinkage by up to 80% and increases in revenues of more than 20% are achievable, even in the early stages of incremental deployment. This paper will focus on fresh produce to illustrate how AI Inventory Monitoring and Management can yield such results. The paper will touch on even more application scenarios with similar if not more impressive results in a store's meat department, deli, bakery, dairy and other departments.

For purposes of describing how an AI Logistics and Inventory Monitoring and Management System functions, as simply as possible, this paper will profile fresh produce inventory for a store's Produce Floor and Fresh-Cut Kiosk. Architecturally, the store has an existing Inventory Management System and Order Entry System, manually managed by the store's Receiving Department and Produce Department personnel. A Cloud interface would be installed and connected to both systems through normal Application Program Interfaces, APIs. These APIs provide the mechanisms for the Cloud AI to access and supervise both systems. Fundamentally, the Cloud AI monitors the level of store inventory, set by the store's AI Demand Planning System, for each product, in real-time, continuously, and manages the "optimal" placing and monitoring of new product orders. The objective of the Cloud AI is to ensure that the store always has the products that are in demand by its customers on its shelves while simultaneously ensuring the highest product quality, lowest product cost, optimal transportation cost, optimal in-store stockroom management and no inventory shrinkage.

For reference, the store facility model we will use in this paper is illustrated here. The store is organized, from a floorplan perspective, with customer checkout stations at the front of the store near the customer entrance and exits. The store's Deli is also at the front of the store to one side. The store's product shelf aisles, with refrigerated display case aisles in the center, are behind the checkout stations. The cold-display meat cases are along one side of the store in front of the meat cutting and packing room for easy servicing by the meat department's staff. The store's fresh produce shelves, tables, and kiosks are along the other side of the store with easy access to the store's inventory stockroom. The inventory stockroom is at the rear of the store behind normally closed thermal-barrier doors. The main section of the inventory stockroom runs the width of the store with multiple thermal-barrier access doors, one on each side and another in the center. This main section is where newly received inventory is stored until it's moved into the store's shopping area, stacked on either side of an aisle running its width. This aisle is wide enough for a conventional hand truck to move through it and manage the placement of boxes and pallets against the stockroom's walls. The stockroom has a refrigerated cold-storage unit at one end for fresh produce storage. The Fresh-Cut preparation-room is in the inventory stockroom next to the produce refrigerated cold-storage unit with its own access. Dairy refrigerated storage and display cases are in the stockroom such that they can be maintained from within the stockroom while providing store customers direct access to the dairy products they display. The store's receiving area with its "open" receiving dock are on the side of the stockroom opposite the produce refrigerated cold-storage, separated by a thermal barrier. Store inventory is received, broken-down as required, inspected, and recorded in the store's inventory system before it leaves the receiving area. This traditional store layout does not need to be physically modified to accommodate Inventory Management Robotics, rather the robotics are designed to utilize conventional floorplans and spaces.

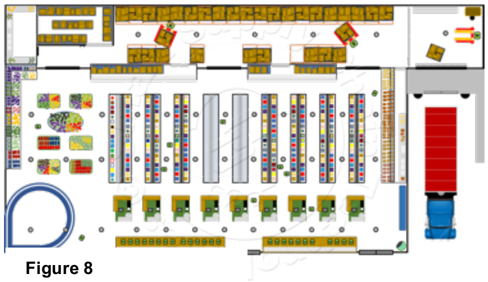


Figure 8

Effective and Efficient Use of Inventory Storage Areas

The key to in-store inventory monitoring and management, and reaching the full potential of just-in-time inventory is reliably knowing what customers want to buy and making sure that those products are in the store and ready to be sold. This begins, in the store, with the effective and efficient use of the in-store inventory storage areas. Inventory Management Robots that work behind the scenes are integral to this success. These cloud-assisted autonomous robots can receive the store's arriving products in the receiving area, evaluate what is being delivered against what has been ordered, issue Blockchain-of-custody ledger entries for the store and the shipper, and then manage the inventory in the store's inventory storage areas, on the shelves, to compost, or through the checkout counter. Our guiding premise for in-store robotics is that robots should be cost-effective, trouble-free, and do task that people can't do, don't want to do, or can't do well. Moving heavy loads, finding specific customers in the store's aisles, and being continuously vigilant in making sure inventory gets on the shelves before its sell-by-date expires and that product with expired dates are taken from the shelves are good examples. To those ends, a variety of robotic designs might be employed. A robotic fork-lift truck like the one pictured, designed such that a robot might move between various fork-lift trucks as well as other "attachments" to carry out a variety of different task.

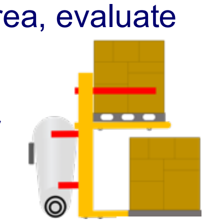


Figure 9

Another particularly intriguing robot concept is that of a small simple robotic Box Mover that can autonomously manage the movement of boxes from the store's receiving area into the its stockroom and even into refrigerated cold storage units. These cost-effective Box Movers will be designed to straddle one another such that a "low-rise" Box Mover can slide under a "high-rise" Box Mover and thus create stacked storage. Box Movers will be able to carry up to 150 kg or so and will be in constant communications with the store's Inventory Management System through integrated Wi-fi and Sub GHz electronics. Box Movers will communicate with each other through Sub GHz communications and will use that communications with Wi-Fi for triangulation-navigation. Box Movers will use cost-effective ultrasonic collision avoidance and not lidar for navigation assistance.

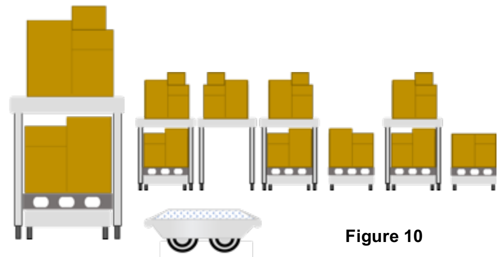


Figure 10

Inventory Management Robots might even be able to break down pallets in the receiving area into their boxes, locate and scan their barcodes and inspect each box for critical damage. Once a delivery is accepted, an Inventory Management Robot, communicating with the Inventory Management System, might issue Blockchain-of-Custody and then proceed to move the boxed and palletized inventory into the store's inventory storage areas.

The store's inventory storage area is typically a long and wide corridor running across the width of the rear of the store. This is a temperature-controlled area isolated from the receiving area by hanging thermal barriers to protect it from the fluctuations caused by exposure to the outside ambient while receiving deliveries. The store's inventory area main cold-storage unit is typically on the far side of the inventory storage area, opposite the receiving area to further minimize the temperature impacts of proximity to the receiving area. The temperature closer to the receiving dock is allowed to reach as high as 12°C (54°F). The temperature in the inventory storage area, close to its cold-storage unit, is typically around 7°C (44.6°F), adequate for short-term produce staging. The cold-storage unit temperature should be set between 2°C (36°F) and 7°C (44.6°F), according to FDA data, www.fda.gov/food/resourcesforyou/consumers. Managing the ambient temperature for multiple kinds of Produce is a complex task. Monitoring these temperatures, in real-time, and reporting them to the Inventory Management System, is critical to reducing product shrinkage. Strategically placed real-time sensors and roving store robotics that might check and record cold-case temperatures a couple of times a day are perfect for this task. In our research, the store kept its Produce refrigerated cold-storage unit temperature between 2°C and 4°C pretty reliably but its in-store cold-case temperatures varied beyond 7°C often and would have benefitted from more vigilant monitoring.

For our purposes, the inventory storage area has been "virtually" partitioned into pallet size "slots" along both of its sidewalls. Virtual partitioning means that each slot is defined by its geospatial X-Y coordinates on the stockroom floor as determined by Wi-Fi / Sub GHz triangulation. The Inventory Management System uses this virtual slot map to refer to where inventory is temporarily stored, palletized or boxed, in the stockroom before it's moved to the store's retail area. Inventory Management Robots, communicating with store's Inventory Management System are cognizant of and utilize these virtual slots.

The store's Inventory Management System AI assigns stockroom slots to incoming pallets and boxes based on available slots, their product ambient temperature requirements, proximity to specific cold-storage units, projected slot demand for other products not yet arrived, etc. This is a continuous process which often requires the Inventory Management Robot to redistribute pallets and boxes in the stockroom throughout the day, including into the refrigerated cold-storage units for dairy, meat, and produce and to the store's retail staging areas.

Produce pallets being moved into the refrigerated cold-storage units are always broken-down to box-level with their box barcodes scanned by Inventory Management Robots. The barcodes of empty boxes are scanned again as they are emptied and removed for the cold-storage unit. Displays near the doors of the refrigerated cold-storage unit reflect, for Produce and Fresh Cut personnel, what inventory is currently in the cold-storage unit. Again, the cold-storage unit is organized into virtual inventory slots by the Inventory Management System using the same triangulation techniques described earlier, albeit less precise as box sizes can vary widely. Produce department staff and Inventory Management Robots utilize these virtual slots to find specific produce in the cold-storage unit. The system ensures that produce personnel always know what's in the cold-storage unit and maybe more importantly what's not, and where it is. This is particularly important when the cold-storage unit has two access points, as in our example model, one from the main stockroom area and another from the Fresh Cut Preparation room. Fresh Cut Room personnel are continually taking produce from the cold-storage unit, sanitizing each item in a wash, apples, pears, strawberries, cucumbers, etc. before slicing, dicing and combining them into packaged cocktails and placing them in the Fresh Cut Store Display case for sale.

The store's Inventory Management System is continuously monitoring everything to ensure that all inventory in the stockroom and cold-storage areas get to the store's retail area shelves well before their "sell-by-dates" expire. This monitoring, by the Inventory Management System's AI, continues after those inventory products are moved to various retail locations around the store, including prepared Fresh Cut Products, to ensure that they are sold or removed from the shelves before their "sell-by-dates" expire. Again, the Inventory Management System's AI objective is to ensure that the store always has the products that its customers want and that they don't expire before being purchased. To further this end, the store employs other AI technologies in its retail areas.

Image Recognition for Inventory on Shelves

Robots are not always the best solution. Our on-the-ground research (7), circa late 2017, shows little interest in "information" robots, those that answer questions posed by random consumers. We talked with a supervisor at a community information center, what one would think was an ideal location to deploy an information-robot, that asked the company that offered the robot, for free, to come and take it away. They reported that the robot had limited capability and was not able keep up with anything other than simple "shallow" exchanges. Beyond that the robot often ran out of battery, sometimes mid-conversation, and was unable to successfully reconnect itself to its charger station. The customers we spoke with in one grocery store over several weeks and others over shorter periods reported that their experiences with "conversational" robots, albeit not many in a grocery store, wasn't very helpful and not worth the trouble to find the robot. A number of these consumers found them limited in capability and therefore not actually helpful with a limited set of "fixed" responses to questions. A number of customers we spoke to suggested that they had a better experience getting help from their smartphones which they always had fast and easy access to. The two most reported aggravations reported by the customers we spoke to were not being able to easily find products in the store and store aisle congestion. A number of these customers suggested that a smartphone “app” that could tell them where a particular item was in the store would be very valuable. Even though the underlying technologies have and continue to improve, S2CT has taken these insights to-heart and endeavors to only position robots for what we consider robot task and use other less expensive and simpler technologies for Inventory Monitoring and Management Solutions whenever they make sense. Grocery store shelf inventory monitoring is an example of just such a case. Instead of using robots roaming through the store’s aisles and adding to aisle congestion to scan shelf inventory for the Inventory Management System, S2CT proposes using less problematic and cost-effective Fisheye Cameras mounted in the store’s ceiling.

High Definition Fisheye Cameras are positioned throughout the store, at strategic locations, to provide images of all the inventory on the store’s shelves, display cases and kiosks. A fisheye camera captures hemispherical images of its field of view, from the center point of its lens out 90° or so in all directions. When positioned between and above two aisles, the cameras will capture the images of the shelves on both sides of the aisle, from the floor to essentially to the height of the camera. These distorted fisheye camera captured images are either demorphed by software in the cameras themselves or sent to the Inventory Management System’s AI software for demorphing before being processed [8]. Processing means using AI image recognition software and product data to identify the products on the shelves in its field of view. AI software can recognize Fresh Cut product packages on the shelves that were made to prespecified recipes or even ad hoc packages of random cut produce, blackberries, blueberries and dates in shrink wrapped trays for example. This technique can approach 100% shelf inventory accuracy.

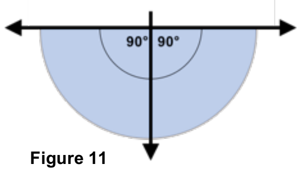


Figure 11


Figure 12

The Inventory Management System’s AI manages how often each camera captures and sends images for processing, from every once in a while to multiple times a minute, if circumstances warrant it. The Inventory Management AI can compare multiple time-lapsed images to each other to detect changes, compare its findings with images from other cameras, including images of products in shopping carts, analyze checkout data, and much more. The Inventory Management System’s AI can correctly identify with great accuracy products that have been moved to a wrong spot on a shelf, have fallen over and are upside down, if not instantaneously over several minutes and images. Think about a Fresh Cut Blueberry Yogurt Cup that has fallen-over on its side, near its previous shelf location. The AI can identify a round object with a size consistent with a Fresh Cut cup having a white substance with a few small blue objects visible in it. The AI determines that the round object is a plastic cup bottom and that the white substance is likely yogurt and the blue objects are likely Blueberries. Using these determinations, the AI identifies the fallen object as a Fresh Cut Blueberry Yogurt Cup. The AI also “learns” over time about customer behaviors , product image details, and other factors that assist it to carry out its shelf inventory monitoring assignment. Finally, the Inventory Management System can ask store personnel for assistance. This all leads to unimaginable shelf inventory monitoring and management used to manage inventory across the entire store and even beyond.

Customer Service Robotics

Consistent with our perspective on using autonomous robots only for task that require them, we have developed a concept for a Grocery Store Personal Assistant Cart Bar, GSPACB, that is nonintrusive and likely very cost effective even when deployed in larger numbers [9]. GSPACBs will incorporate many of the same features that a traditional autonomous robot might have but in a very familiar form factor, a traditional grocery cart. A GSPACB is actually an IoT device adapted to either replace the traditional bar on the grocery cart or be fitted onto an existing grocery cart bar.

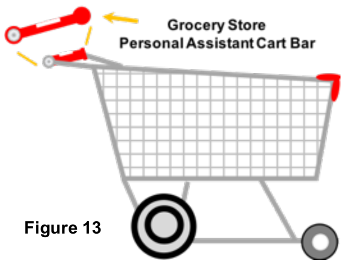


Figure 13


Figure 14

A basic GSPACB will be battery powered with rechargeable batteries. A feature might be the ability to recharge the GSPACB's batteries through the movement of the cart, the turning of the cart's wheels. GSPACBs will have integrated Wi-Fi and Sub GHz wireless communications used for communications with the store's Inventory Management System and cart geospatial position tracking. For note, such tracking can yield geospatial position resolutions of a few centimeters and could easily extend into a store's parking lot. GSPACBs will have a small integrated display with touch for occasions when it might be useful. GSPACBs will feature voice and speech synthesis capabilities through the Inventory Management System's AI. Fundamentally, a GSPACB is a cost-effective cloud connected device with AI capabilities only limited by the compute power in its cloud and the desires of the consumers and stores it serves.

Customers will retrieve a cart, with a GSPACB, from the front of the store as they enter just as they would a traditional cart. The customer might transfer a shopping list from their smartphone to the GSPACB or even build it verbally while shopping in the aisles. The customer might log into a store-account, using the GSPACB's touch screen, that they've previously setup to retrieve a shopping list that they've uploaded. The store-account could offer the customer a number of benefits, to encourage its use, like saved shopping history, in-store special offers, digital coupons, shopping advice, and shopping management features. etc. The GSPACBs could alert the store's stockroom that shelf-inventory for a particular product on the customer's shopping list is low and request its replenishment. The GSPACB's display / voice might inform the customer of items on their shopping list that are not currently in stock at the store and offer alternatives, future home delivery or future store pickup. The GSPACB might answer questions about products, ingredients, dietary information and product comparisons, help understanding marketing statements like "fresh", "natural" and "organic", etc., "normalized" unit price comparisons, country of origin information, date information, product alerts if there are any, etc. One of the best features, possibly the number one aggravation customers expressed during our research, is the ability to tell the shopper where a particular product they came to the store to purchase is on the store shelves. A knowledgeable shopping companion.

Advanced GSPACBs might incorporate cameras on either side of the cart-bar capable of capturing images of inventory on the shelves it passes by, on demand for the shopper or just transparently for the Inventory Management System. Advanced GSPACBs might incorporate a motor on the cart that either assist in moving the cart from place to place or even makes it autonomous with the customer just walking behind. Another pain-point addressed. Shoppers reported often be aggravated by other customers abandoning their carts while they search for something or just peruse the shelves. A manager of one of the stores in our research said that customers expect other customers to be in their way. Autonomous or semi-autonomous carts could communicate and cooperate with one another when congestion happens using their tracking capabilities to keep the aisles as clear as possible.

AI helps to make the shopping experience pleasant by providing smoother store operations and a better store shopping experience. AI Inventory Demand Planning and AI Inventory Management ensure customers will find the products that they want at the store or at their front doors. Another key to doing this successfully is the store's ability to monitor its inventory supply chain to ensure that the products its systems have ordered and count on being in the store actually get there. This means access to "real-time" data from the supply chain! To that end S2CT has developed a robust supply chain monitoring and management model with its underlying technologies to make this seamless.

Dynamic, Secure, Point-to-Point, Private Data Sharing Network with Blockchain

By Jim Davis and Eric Lam, Ph.D.

How to share supply chain data safely and securely

As early as mid 2006, S2CT principals realized supply chain companies and stakeholders already record and save all the relevant data regarding products they ship, transport, store, and ultimately deliver to end customers, in their private company databases. This data uniquely identifies cargo, when and how it was shipped, what were the special handling arrangements, when did it arrive at a shipping depot, how was it consolidated and shipped with other cargo, when did it leave the depot, when did it arrive at the shipping terminal, etc., etc. Data at each change of custody was in a database somewhere, put there by whatever technology the particular company found appropriate for its business without being encumbered by technology compatibility with others. The problem was how to allow each of these companies to safely and securely share this private data, without risk of compromising its privacy, with other companies when there was a clear business benefit.

Blockchain-of-Custody for cargo

S2CT principals have been thinking about and developing components of a distributed private data sharing technology ever since they theorized an architecture that in many ways

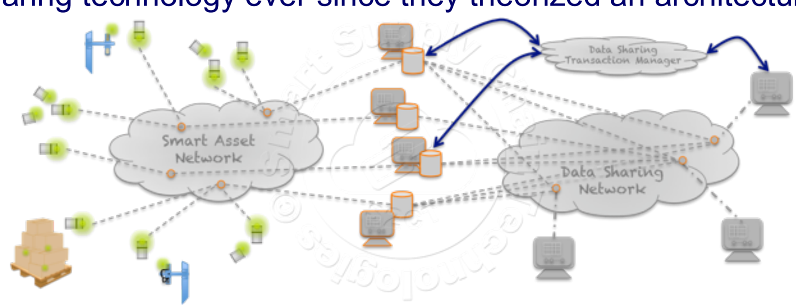


Figure 15

is similar to what the industry today refers to as Blockchain. This original concept, as it still does today, was able to track and monitor "things" across a far-flung landscape of distributed private databases, across a Blockchain-of-Custody, using what we referred to as the Open Platform Specification [10], circa 05/2006. Originally the goal was to track and monitor things as they moved through their supply chain journeys and chain-of-custody without relying on a central data repository or specific electronic hardware attached to them. In its simplest interpretation, Blockchain is a distributed ledger that securely records transactions between two parties. The transfer of something, bitcoins or cargo for example, from one party to another party, is securely recorded in each party's private ledger. Each record representing a block, and a number of blocks strung together, a Blockchain. Without pressing the analogy too deeply, S2CT sees and uses its Exchange Verification (EV) as a form of Blockchain, in this case, a Blockchain-of-Custody for cargo. When a cargo arrives at a destination, the carrier and the receiving party execute an Exchange Verification. The carrier reports what it has delivered, along with data associated with its condition if applicable, to the carrier's Asset Management System, and the receiver reports what it has received along with the same condition data to its Asset Management System. A cloud application compares the data and if it agrees, an EV entry is made in both Asset Management System databases. These two disjoint entries, in different private databases, represent a successful change in custody and a block in the Blockchain. We have evolved these original concepts and the underlying technologies over the years into what we now refer to simply as the S2CT Data Sharing Network.

S2CT Data Sharing Network

The S2CT Data Sharing Network fundamentally connects Data Sharing Databases of different companies together in a secure peer-to-peer connection, for the purpose of sharing data between them, when and while their interest intersects. S2CT's Secure Peer-to-Peer Data Sharing Network Technology is applicable to a wide range of secure data sharing Commerce 4.0 applications including supply chain asset management. In a supply chain application, companies are sharing relevant data from their underlying Asset Management Systems to track and monitor assets, cargo, equipment, containers, vehicles, etc., as they move through the supply chain and their chain-of-custody. A comprehensive description of a supply chain journey, including the use of the Data Sharing Network, is extensively presented in the S2CT's White Paper entitled "IBM Bluemix, Blockchain, S2CT's Global Asset Management Architecture and Ubiquitous Wi-Fi Render GPS and Digital Cellular Networks Communications Obsolete in the Global Supply Chain" available on the S2CT website, www.s2ct.tech/white-papers.

Data Sharing Application and Data Sharing Database

Structurally, each company's Data Sharing Network is composed of two elements, a "Registered" Data Sharing Application (DSApp) and a Data Sharing Database (DSDb), typically hosted on the same server as the company's Asset Management System. The DSApp provides the mechanism for the Data Sharing Network's registration and administration as well as managing the networks data and communications security. The DSDb provides a common data interface type between Data Sharing Networks and for the DSApp to use with local databases such as the Asset Management Database and various legacy databases that it might exchange data with.

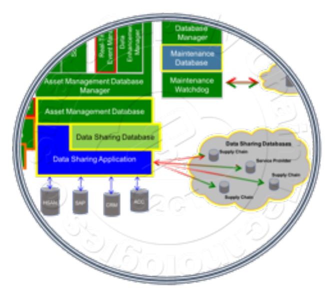


Figure 16

Registration in the S2CT Data Sharing Network Cloud and the Data Sharing Network technology is free, Data Sharing Network users will pay a small micro-transaction fee for requesting data but will also be able to share their data for free. Registering a Data Sharing Network provides it with a unique ID used when communicating with other Data Sharing Networks. Registration is when and where the Data Sharing Network's security begins. Registration generates the network's initial Dynamic Node Authentication key and its PKI key pair used to encrypt and decrypt data being communicated between Data Sharing Networks.

S2CT Data Security Model

When two Data Sharing Networks connect together in a peer-to-peer connection, they do so through a Virtual Private Network (VPN) [11]. The VPN connection is only established between two authenticated registered DSApp nodes in much the same way that two devices authenticate themselves and exchange data in the S2CT Data Security Model, with Dynamic Node Authentication. A comprehensive description of the S2CT Data Security model, including Dynamic Node Authentication, is presented in the S2CT's White Paper entitled "Data Security in the Global Supply Chain" available on the S2CT website, www.s2ct.tech/white-papers. Once authenticated and the connection is established, each node in the Data Sharing Network connection sends its Public Encryption Key to the other node. Data is shared between the nodes using a dual "random-key" encryption scheme, similar in concept to a Public / Private Key method, PPK [12]. In this asymmetric key encryption method, anyone can encrypt messages using the public key, but only the holder of the private key can decrypt the message because the keys in the pair are mathematically related. Said more simply, whatever is encrypted with a Public Key may only be decrypted using the paired Private Key. Data sent from one Data Sharing Network node to another is encrypted with the receiving node's Public Key. The receiving node decrypts the data with its Private Key, kept and managed by the S2CT Data Sharing Network Cloud, effectively acting as the "Certificate" provider. Both keys are randomly regenerated and redistributed.

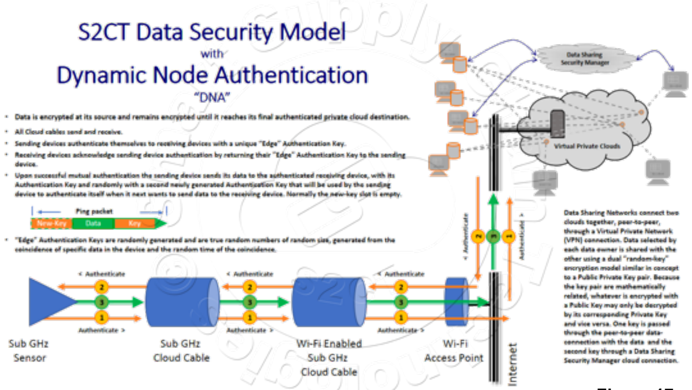


Figure 17

Artificial Intelligence in S2CT Data Sharing Network

The DSApp manages all data written into and retrieved from its DSDb. The DSApp manages requests to and from other Data Sharing Networks for data, and the Artificial Intelligence [13] (AI) Rules for managing impromptu dynamic connections. Through the DSApp, the Data Sharing Network Administrator connects the DSDb to the company's Asset Management Database and any other databases available from the server that might provide pertinent data, like order entry, shipping, receiving, finance, etc., for asset management. The Administrator sets up the data sharing rules for the DSApp, like share Basic Data with any authorized and authenticated Data Sharing Network, identify as "Trusted" Data Sharing Network requesters for sharing various levels of extended data, etc., for example.

AI plays an important role in S2CT Data Sharing Network as it has in many of the concepts developed and rolled out by S2CT principals over the years. Five plus years of battery life for an electronic communications device wasn't the result of break-through battery technology but rather the device itself intelligently deciding when to use the battery's energy and when not to. The device might decide to terminate a Wide-Area-Network connection attempt after observing that the attempt was struggling, noting that the probability of its success was less than optimal, that the last connection was only hours ago, knowing its data would not be lost and reasoning that the probably of making a connection more easily within the next few hours was high.

AI is what makes S2CT Data Sharing Network so powerful. You can simply think of Artificial Intelligence as the difference between software using a table with thousands of entries to determine every step that it takes and a table with just a few key parameters in it that are used over and over again by the software to make decisions around the ever-changing data and circumstances. AI in the Data Sharing Application is used to determine what data sharing connections to make and when to terminate them, what authorized data to share with which supply chain partner based on reasoned benefits, is the EV successful or not and what to do about it if it isn't. Sounds simple but in many cases, it's not!

When the EV Blockchain-of custody is not digitally shared it's the DSApp's AI that non-heuristically finds the correct Data Sharing Network to connect with, based on reasoning. The DSApp can dynamically decide to share cargo-specific historical temperature data to a receiving supply chain partner to facilitate a corrective action that might prevent the cargo from deteriorating. When the EV requests from both the delivering party and the receiving party reports slightly different data, temperature from two different sensors for example, AI can either reject the EV and issue a warning to be resolved by personnel or conclude that although different, the reported temperatures are essentially equivalent. Of course, the level of freedom "given" to the DSApp's AI is completely up to its user, Administrator, and will very likely evolve over time as trust builds.

Independent peer-to-peer connections

Operationally, the S2CT Data Sharing Network model is built around the notion that each data sharing connection operates independently as separate peer-to-peer connections. These independent connections are managed by each network's DSApp to send and receive data, directly, from and to their respective DSDb's. The source data, that is being shared, is retrieved by the DSApp from "local" databases like the Asset Management Database and other local databases that hold data relevant to the specific data sharing connection. Relevant data is any data that the source data provider believes will benefit its interest. The source data provider's supply chain management might be enhanced by this specific receiving party knowing the next destination of a vehicle delivering a cargo. That data retrieved by the DSApp from the source provider's shipping database is copied into the DSDb so that all Data Sharing communications is in a common format and protocol. Each DSApp manages the complexity of interfacing to disparate database types and formats, depending on ODBC[14] and JDBC[15] to ease those rigors. All of this is setup and controlled explicitly or through dynamic AI rules by the Data Sharing Network Administrator.

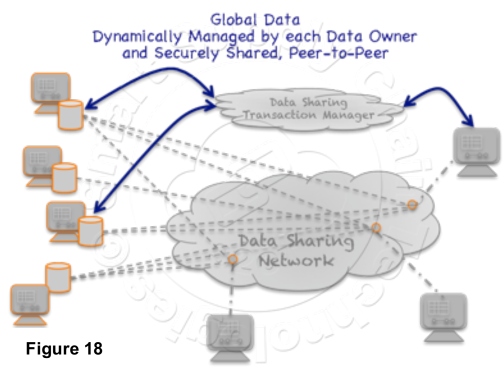


Figure 18

Produce Market example

Think about a Produce Market managing its inventory. The Produce Manager places an Order for chilled produce with a local provider that provides produce to the market on a regular basis. The Produce Market and the Produce Provider both have Data Sharing Networks and have shared supply chain data previously.

The Produce Market's Order Entry System triggers the Produce Market's DSApp to establish a Data Sharing Network secure connection with the Produce Provider's Data Sharing Network. Both companies will be able to monitor the Produce Provider's delivery vehicle's progress and its cargo’s ambient environment throughout its journey, cargo area temperature and humidity, and the vehicle’s on-time arrival at the Produce Market’s Receiving Dock. Upon the cargo’s delivery, both the Produce Market and the Produce Provider’s driver execute an Exchange Verification, both company’s Asset Management Systems comparing what was delivered, to what was received. When the EV compares, an EV Blockchain-of-Custody entry is made in both company’s Asset Management System recording the successful change-of-custody.

Share readily available data securely to get ALL data needed

In the big picture, the 90/10 rule applies. The 90/10 rule holds that many times 90% of a task can be achieved with 10% of the effort required to complete the full task and the last 10% will require 90% of the total effort to complete. Most companies and supply chain stakeholders will get all the data they need just by sharing the data they have been collecting for years. Data like: when the factory or producer ships a product, the products condition as it travels across its journey, when that product arrives at its first stop, the shipping depot, when it leaves the depot in a container, the container’s ID, when it was loaded onto a vessel, when it arrives at its destination port and when it clears customs, when it leaves the port for another transportation depot, when it arrives at that transportation depot and leaves again for delivery to its final destination – all this just by sharing data that is already readily available across the global supply chain. Powerful!

Clearly, Data is everything to the supply chain and AI. To further those data ends, S2CT has developed and demonstrated an amazing AI driven, cloud connected device called the Cloud Cable. It’s just that, a device that connects any asset, actively or passively, to any cloud platform for its application services support and depositing its real-time data for cloud analytics to use.

The Amazing Little Cloud Cable

By Jim Davis and Eric Lam, Ph.D.

The S2CT Cloud Cable is our entry level Asset Monitor product concept. Its basic intent is to connect disjoint points together, wirelessly, using HME Sub GHz[16] communications. The Cloud Cable can be generally thought of as providing the functionality of a physical cable connecting a target point, the point where the Cloud Cable is installed, to one or more other points. With that said, the Cloud Cable is a little more capable than a wire as it is microcontroller based to fully execute S2CT device-to-device authentication, data encryption and decryption, advanced power management, and can be programmed to execute a single or limited number of application tasks. Given the current state of even low-end microprocessors, powerful, with abundant memory and support for on-board storage, these tasks can be quite sophisticated. Cloud Cables with integrated sensors can be configured and programmed to operate as Proportional Integral Derivative (PID)[17] System Controllers. Such a PID Cloud Cable could manage the operational parameters of refrigerated assets, reefer trucks and containers and cold storage units using classical, sophisticated, PID equations:

$$u(t) = K_p e(t) + K_i \int_0^i e(\tau)d\tau + K_d \frac{de(t)}{dt}$$

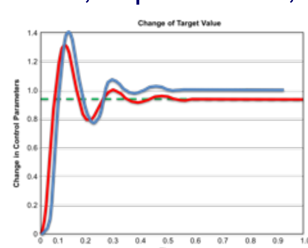
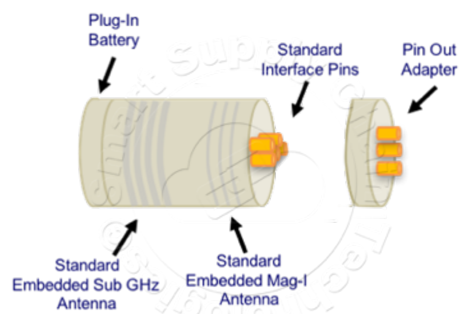


Figure 19

This requires the Cloud Cable's microcontroller to continuously evaluate the cold unit's environmental data, from its sensors, and to make continuous adjustments to the unit's operating parameters driven by the PID equations. Cloud Cables can be "Smart".

More typically, Cloud Cables rely on other devices they connect to and the cloud for more sophisticated multitasking functionality and data analytics. S2CT's White Paper entitled "IBM Bluemix, Blockchain, S2CT's Global Asset Management Architecture and Ubiquitous Wi-Fi Render GPS and Digital Cellular Networks Communications Obsolete in the Global Supply Chain" describes a comprehensive deployment and use model of a variety of Cloud Cable configurations, www.s2ct.tech/whitepaper-cloud-blockchain-wifi.

All S2CT Cloud Cables are programmable microcontroller-based devices, have plug-in Battery Power Systems, integrated Sub GHz subsystems with an embedded Sub GHz antenna, integrated Magnetic Inductance (Mag-I[18]) with an embedded Near Field Mag-I antenna, a standard set of six programmable Input / Output pins, a minimum of 8Kbytes of non-volatile RAM for Data Logger (64 pings). The standard Battery Power System can house up to 3 AA batteries with "Smart" Advanced Power Management for extended life. Standard I/O adapters are available for USB, Serial, GPIO and UART data plugs. Entry level Simple Cloud Cables are intended to communicate through Sub GHz to Wi-Fi enabled Cloud Cables or directly to Sub GHz enabled Wi-Fi Access Points. Simple Cloud Cables will sell for around $25 USD and Wi-Fi enabled Cloud Cables for around $30 USD. A single standard 802.11b/g/n Wi-Fi Access Point can provide network communications to hundreds of Cloud Cables in its field of coverage.



Cloud Cable with I/O Adapters
Figure 20

Flexibility in use

S2CT Cloud Cables will be available in a variety of configurations and can easily be customized for a specific task. Cloud Cables can be permanently or temporarily installed on or in an asset, containers, truck trailers, truck cabs, chassis, railway cars, vessels, gensets, spreaders, cranes, forklifts, pallets, warehouses, shipping depots, factory floors, truck cabs, cold storage units, dry storage units, etc., the list is only limited by one's imagination.

Cloud Cables can be installed in an asset by themselves or as "Masters" in local-area networks of Cloud Cables. A Cloud Cable local-area network is typically comprised of a master unit and a number of disjoint Cloud Cable slaves. Slave Cloud Cables are placed in the same general area as the master but in locations appropriate for their specific tasks. A Cloud Cable master might be collecting temperature data from its own integrated sensor and from slave Cloud Cables installed in the four corners of a trailer's cargo area. The Cloud Cable Master, aggregates all of this temperature data and communicates it to an Asset Management System where a profile of the temperature gradient across the cargo area can be developed and analyzed.

Movable: ease of installation and deployment

Cloud Cables can be permanently installed on a specific asset or moved from one asset to another. In either case, it is important to know which asset the Cloud Cable's data is associated with. To this end, an inexpensive Mag-I Tag, with a unique embedded digital ID, can be permanently attached in a convenient location on an asset. When a Cloud Cable is installed or moved to a new asset, the installer simply touches the Cloud Cable to the Mag-I Tag and waits a second or so for the Cloud Cable's "Association" LED to blink. When the Cloud Cable is touched to a Mag-I Tag, the Mag-I Tag ID is transferred and stored in the Cloud Cable. That Mag-I ID is then inserted in all data packets that the Cloud Cable communicates to the asset owner's Asset Management System. The Asset Management System can either use the Mag-I ID to distinguish different assets or cross reference them to other asset IDs already used within the asset owner's workflow, a container number for example.

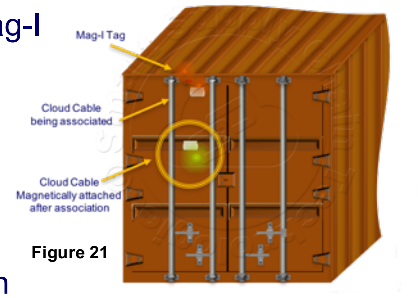


Figure 21

Cloud Cables must also be flexible enough to be deployed in a variety of asset applications, from simple monitoring and tracking to interfacing to sophisticated asset control systems, a cold storage unit's refrigeration controller for example. Simple monitoring and tracking only requires that the Cloud Cable and its "paired" wireless sensors, if there are any, be appropriately installed on or in the asset. Appropriate means in the best location on or in an asset to execute its programmed task and in some cases, it means out of harm's way, blended into the asset's superstructure such that its presence is not obvious. To these ends, Cloud Cables are completely compatible with S2CT's component modularity and universal enclosure concepts(19).

In sophisticated deployments, where the Cloud Cable is a conduit between the cloud and another electronic device, the Cloud Cable must be flexible enough to be connected to any target interface or connector. Cloud Cables meet this challenge with extensive and flexible I/O capability. Our Simple Cloud Cable will provide 6 to 8 GPIO (General Purpose Input Output) pins which can be programmed to interface to a wide range of digital interfaces. This is mostly a physical limitation of the number of pins that can be made available in a small form factor. Consider a simple Raspberry Pi(20) based product can actually support up to 40 GPIO pins along with a number of other pin types including USB and UART. S2CT's entry level Simple Cloud Cable concept makes these pins very flexible in terms of the number of pins exposed, their functions and even where they physically are on the Cloud Cable. The Simple Cloud Cable exposes the GPIO pins on either the side or ends of the device and through adapters, their precise number and physical arrangement can be customized. Maybe more importantly, these pins can be reconfigured to desired protocols, on demand, from the cloud. Immediately after a Cloud Cable is associated with a new asset, it communicates with the asset owner's Asset Management System in the cloud. During these initial communications, the asset owner's Asset Management System determines the type of electronics the Cloud Cable will interface to, what software will be necessary to communicate with the specific electronics, and how the Cloud Cable's I/O pins must be configured before they are activated. The Asset

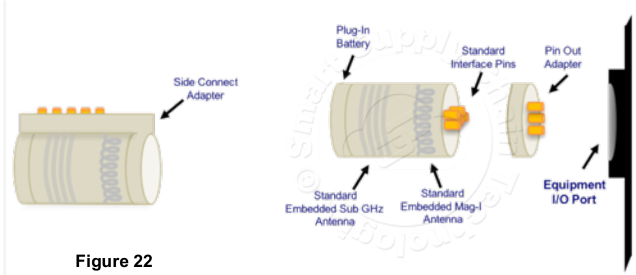


Figure 22

Management System either loads its own communications software for the target electronics or connects with an extended cloud service provider for that software and related services. A cold-storage unit's monitoring and management might be turned over to a Certified Climate Control Services Provider, both capable and authorized to manage the specific electronics. The Cloud Cable's I/O pins are configured and activated by the electronics' communications software.

All of this is extremely important for a Cloud Cable that will move from one asset to another, each new asset being associated with the Cloud Cable, connecting to the appropriate communications software, receiving active pin configurations, and being plugged into the

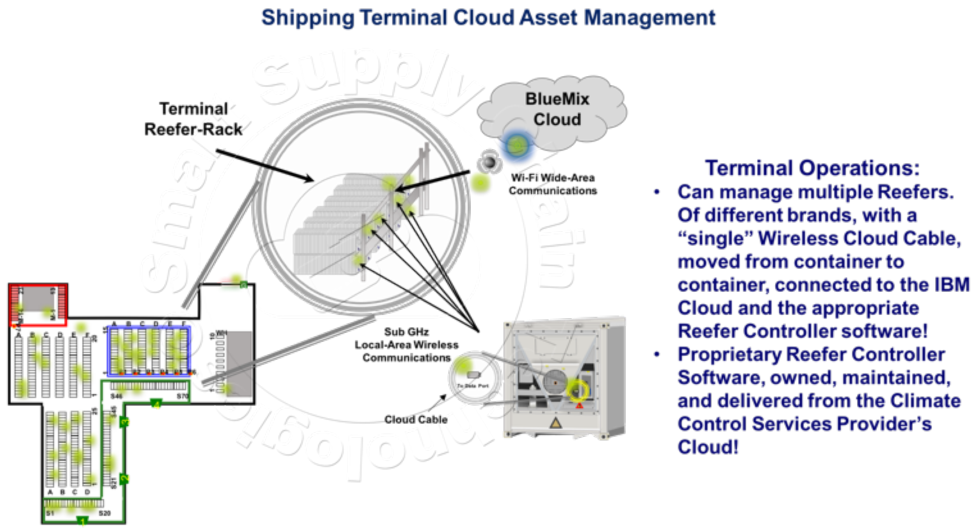
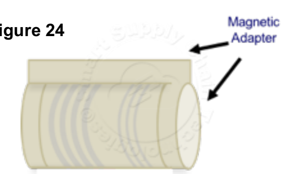


Figure 23

asset's electronic interface. Here the Cloud Cable is clearly a conduit between the asset's electronics and the cloud. Think about a few Cloud Cables being used in a shipping terminal's reefer rack to arbitrarily move from one reefer controller to another to retrieve their trip-data, execute Pre-Trip Inspections and set trip parameters for their expected cargoes. Each time the Cloud Cable is associated with a new asset, the process of staging the correct communications software and reconfiguring the Cloud Cable's I/O pins repeats itself.

Another Cloud Cable feature that enhances its temporary deployment is a magnetic attachment option. A Cloud Cable can be easily fitted with a magnetic side / end cap magnetic adapter that simply snaps onto the unit's basic enclosure. This enables the Cloud Cable to be quickly attached to a metal asset, either along its length or its end, and be moved from one asset to another in seconds. Just touch the Mag-I Tag to associate the Cloud Cable with the new asset, watch for the Association LED to blink, and attach it to the asset's metal superstructure. The cloud and Cloud Cable do the rest!

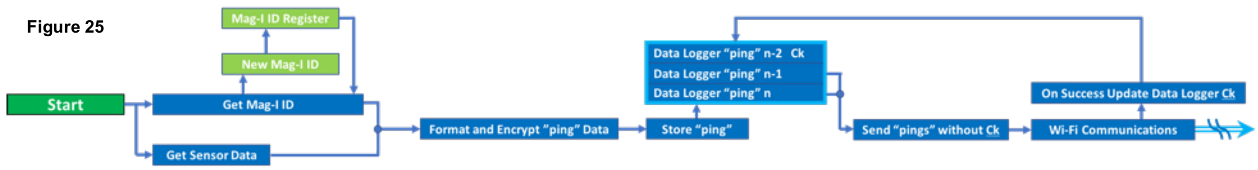
Figure 24



Modification convenience

Cloud Cable features and functionality can be easily modified at production, with modular hardware elements and their underlying embedded software. S2CT will be releasing a number of Open Source Visual Software Library elements, Node-RED[21] code blocks, for Cloud Cables, with its partners, in the near future. S2CT customers and clients will be able to manage their own pipeline of Cloud Cables from their hardware provider of choice with complete access to this ever-growing Cloud Cable Open Source Library. Anyone will be able to use and deploy these library elements as well as modify them, with the Open Source codes, to suit their specific requirements. Modular hardware and the Visual Embedded Software Library[22] allow a hardware manufacturer and its customer to select a core Cloud Cable design and populate it with add-on functions like Sub GHz communications, GPS, LTE Communications, Ultra-sonic sensors, etc., the list is endless. These add-on components will come with their own driver level embedded firmware software and Application Program Interfaces (APIs) and most will already have available Visual Programming Library Elements. The manufacturer simply manufactures the Cloud Cable with the add-on components plugged into the available Printed Circuit Board I/O (GPIO etc.), connects the library software elements as intended using a simple Programming Pad[23] style Interactive Design Environment, simulate its behavior until satisfied, and load the software into the microcontroller application space. Done!

Figure 25



S2CT intends to release and maintain for its customers and clients a similar Visual Programing Library, for the IBM Bluemix[24] platform, for its Asset Management Network software. Anyone will be able to construct their own Asset Management Network in the IBM Bluemix [*] environment with or without S2CT's assistance.

Cloud Cable examples

Following are two Raspberry Pi [*] Cloud Cable examples. The first example is an entry level Simple Cloud Cable, without any Wide-Area-Network (WAN) capabilities. The second example is a Wi-Fi enabled WAN Cloud Cable, capable of connecting to a cloud compute platform for application software support and storing the data its collects.

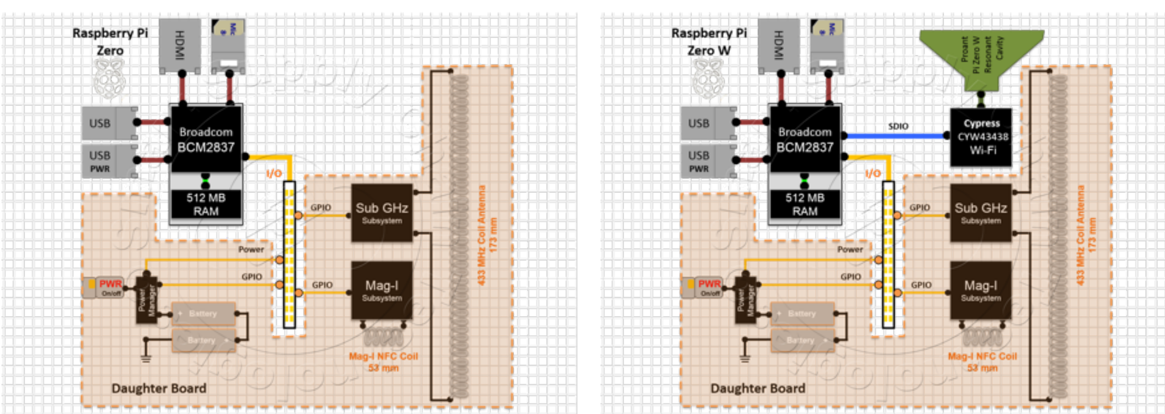


Figure 26 Simple Cloud Cable Wi-Fi enabled WAN Cloud Cable

Entry level Simple Cloud Cables can be Raspberry Pi Zero [*] based with a standard Cloud Cable daughter-card that provides Sub GHz Communications, Mag-I Communications and an S2CT Smart Power System with Advanced Machine Learning Power Management[25]. The Power System accommodates batteries and can also use externally supplied DC power. This simple, inexpensive, entry level Simple Cloud Cable reaches the cloud by connecting through Sub GHz with another device that connects to the Internet, a Sub GHz enabled Wi-Fi Access Point or a Wi-Fi enabled WAN Cloud Cable, for example.

Wi-Fi enabled WAN Cloud Cables can be Raspberry Pi Zero W (*) based with a standard Cloud Cable daughter-card that provides Sub GHz Communications, Mag-I Communications and an S2CT Smart Power System with Advanced Machine Learning Power Management. The Power System accommodates batteries and can also use externally supplied DC power. This still inexpensive Wi-Fi enabled WAN Cloud Cable reaches the cloud directly through its integrated Wi-Fi capability. This is a powerful device capable of operating as either a Wi-Fi Access Point or Wi-Fi node. S2CT is deep into the development of a Wi-Fi Cloud Mesh Architecture (26) where Wi-Fi Access Points, that are far apart and have no overlapping field of coverage, form a Mesh by using the Internet to create a virtual overlap.

Communications operations of Cloud Cable

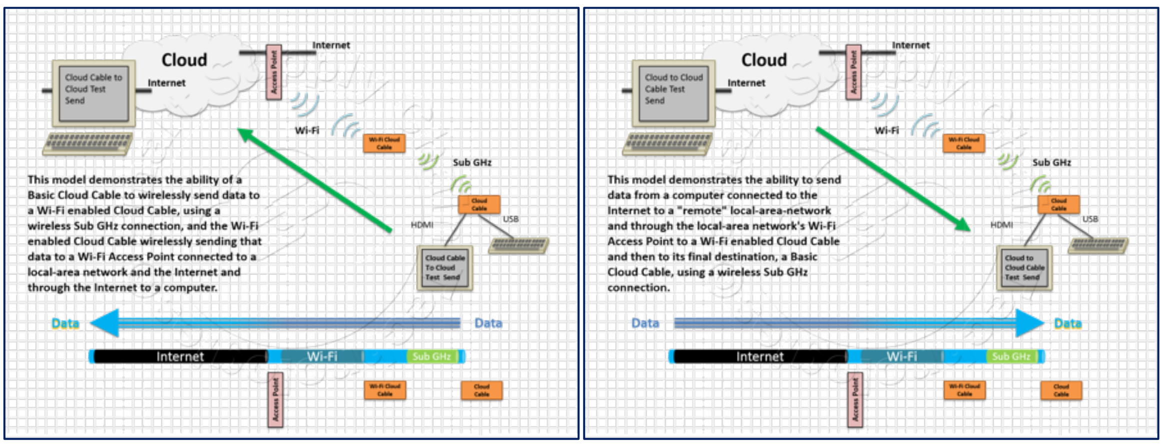


Figure 27

The left pane, illustrates the communications operations of a Simple Cloud Cable communicating its data to a Wi-Fi enabled WAN Cloud Cable, the Wi-Fi enabled WAN Cloud Cable communicating that data to a Wi-Fi Access Point that is hardwire connected to the Internet, and the Internet communicating the data to the cloud and a specific Asset Management System.

The right pane, illustrates the cloud, the Asset Management System, communicating back to the Simple Cloud Cable through the same path but with data moving in the opposite direction. The Simple Cloud Cable might have informed the Asset Management System that the temperature in its cargo area had reached an alert point, too hot or too cold. The Asset Management System responds by sending a command to the asset's refrigeration controller to modify its output temperature to achieve a specific goal temperature. The Simple Cloud Cable delivers that message to the refrigeration controller and it executes the instruction.

The amazing little Cloud Cable!

For all of these devices the security of the data they handle and communicate is paramount to both the consumers and the stores. There are almost daily news reports of data breaches at huge companies, even at Amazon and Walmart (*), that expose the personal data of unsuspecting consumers costing them huge sums to address the breach point and more to restore their customer's confidence. Data security is pervasive throughout S2CT's End-to-End Supply Chain Planning, Monitoring, and Management devices, software and solutions. The following section will offer a deeper dive into our data security approach and its rationale.

Data Security in the Global Supply Chain

By Jim Davis and Eric Lam, Ph.D.

The security of data communicated to and from assets traveling in the global supply chain has a number of underlying motivations. First, asset owners are interested in ensuring that no unauthorized persons gain access to their private data, for both competitive as well as liability issues. Competitive “intelligence” is pretty straight forward. Liability issues are more complex and are generally better served by a complete data picture which can often be quite different than the picture developed just from data from the assets.

Asset owners are also interested in ensuring that the data they receive from their assets in the field, is legitimate and has not been tampered with for illicit purposes. Making a container’s door appear sealed when it isn’t, is a good example. In the new world of connected assets, with multiple devices collecting and reporting data as they travel through the global supply chain, the opportunity for such intrusions abound. These underlying issues that drive the need for data security are too complex to be adequately addressed in this paper. Suffice to conclude, that if technology can ensure that only those that are explicitly authorized to get the data, get it, and that all of the data they get is legitimate, the key issues surrounding the need for data security are addressed.

Security: make it difficult and costly, no easy targets

We point out upfront, that we don’t actually believe it is possible to develop data security that can’t be defeated. This has been demonstrated many times over the years since the inception and spread of personal computers and digital data stored on disk drives. This was again recently demonstrated, after these many years of effort by many companies and researchers to develop fool-proof data security, by the U.S. FBI, with help from professional hackers, cracking an Apple iPhone’s security to get at its data [27]. So, we approach security for the global supply chain from the perspective that making a data security breach difficult and costly is the objective. Even though the FBI was able to break the iPhone’s security, it was not easy and their efforts and cost clearly demonstrate that it was the potential value of the iPhone’s data that drove them. The underlying point here is that hacking has a cost to value consideration and more often than not the potential value of hacked data is what draws hackers. Hackers logically weigh the effort and cost to get targeted data against the value of the data prize. In the FBI case, it was the value of knowing what information could be brought to light by accessing the data on that particular iPhone that justified their efforts. That’s not the typical case. Demonstrating the more usual case were the Amazon breaches [28] in 2015 and 2017, where the expected reward for those efforts were large amounts of data that could be monetized, consumer credit card and other personal data. The hackers were confident that at least some of the hacked data would be valuable, simply based on the volume and diversity of the data, and that there was a potential that most of it would be. Supply chain stakeholders can draw their own conclusions regarding depositing their data into central repositories where the value of a break-in is the value of the aggregate-data in the repository.

Data encrypted at source

It is not an objective of this paper to present even a simple tutorial on the complex technologies of data security and encryption but for purposes of laying out the S2CT Data Security Model, for the global supply chain, we will need to describe a few of the key aspects and considerations. The aforementioned Amazon breaches and the

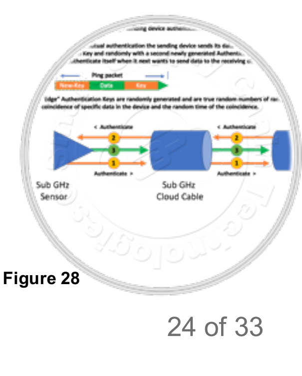


Figure 28

breaking of the Apple iPhone security were certainly not accomplished by simple brute force. That is, not by finding and trying all the possible binary combinations until the correct encryption key was found. Even 128-bit encryption would take a supercomputer, quantum computers aside, years to try all possible combinations to find the correct encryption key, 2^{128} combinations. Beyond the iPhone's data encryption, a 4-digit access pin with embedded software that would have erased the iPhone's encryption key after only 10 unsuccessful attempts, further protected its data and ruled out brute force methods. It is reasonable to conclude that the FBI in 2016, with the help of the outside hackers, the iPhone physically in hand, perhaps Apple's help, and reportedly special hardware developed specifically for the task, also used additional sophisticated methods to gain access to the locked iPhone's data. The S2CT Data Security Model emulates these concepts and strives to make supply chain monitoring devices equally difficult and costly for a would-be hacker to overcome.

The first line of defense is that all data is encrypted at its source, selectively with 64-bit, 128-bit, or 256-bit AES Encryption [(29)]. Data "in-flight" is never unencrypted. A Sub GHz temperature sensor device in a truck trailer's cargo area receives temperature data from its attached sensor, immediately encrypts it, stores it in its encrypted form in its data log, and sends it in its encrypted form to an authenticated end-point destination. End-point destinations can be other authenticated Local-Area-Network devices or an authenticated designated Asset Management Cloud. Only authenticated end-point destinations can decrypt data. Several temperature sensor devices, placed strategically throughout a container's cargo area might each send their data, wirelessly, to the same authenticated Cloud Cable, also in the cargo area. The authenticated Cloud Cable decrypts and aggregates the data from each sensor device for real-time analysis and potential consolidation. The Cloud Cable encrypts and stores its analytical output data, and potentially selected data from the sensor devices, and sends it to its authenticated designated end-point Asset Management Cloud. Again, the Cloud Cable data is encrypted as it passes through a Wi-Fi Access Point and the Internet to its end-point destination.

Authentication is a must when sending or receiving data

The second line of defense is that data can only be sent to or received from "authenticated" devices through the mutual exchange of authentication keys. A device that wishes to send its data to another device or the cloud must authenticate itself to the destination and also authenticate the destination. Wide-Area-Network devices like Wi-Fi Access Points and other broadband communications connections are authenticated as encrypted data passes-through devices using standard security methods. Clouds, ultimately servers connected to the Internet, that these pass-through devices connect and send data to, are authenticated using S2CT's standard mutual exchange of authentication keys security method.

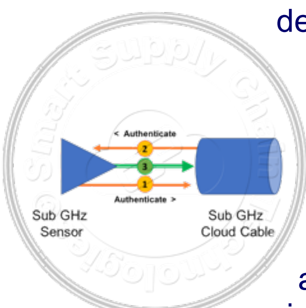


Figure 29

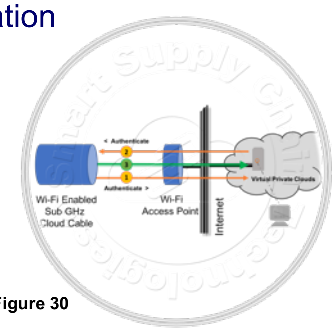


Figure 30

Own random-based authentication key for each device

The third line of defense is rooted in the idea that each device in the network is independently protected with its own random-based authentication key that is only exchanged with devices it is setup to communicate with directly. Randomness is hard to achieve but is essential to strong key security. The S2CT model achieves this randomness for every device at the device level. Device authentication keys are changed randomly over time, based on an algorithm that manages the random periods between the changes as well as the key and key structures themselves. Each device's key generator is programmed to generate a new key after a randomly set period of time, based on the coincidence of random device events and data. The time when the tenths place value in the device's internal temperature data is equal the tenths place value in the device's ambient temperature sensor data and the minutes value of the device's clock time is an even number. When these events and data values are coincident, the device's key generator then uses this same random data to generate the device's new random number authentication key, select the events and data that will be used to generate the next key, and the minimum period before the next change key cycle begins.

Device level authentication begins at manufacturing when a "production" random authentication key is generated, encrypted and stored in the device and the device owner's Asset Management System's device installation manager's secure database. Devices are never openly vulnerable. The Asset Management System communicates the device's "production" authentication key to selected devices already in the field, in anticipation of the device's installation, or alternatively when an already installed and authenticated device request verification of a "new" device, when it tries to connect, from the cloud.

A little extra: random data breadcrumbs

After all this, the security of each device comes down to a random number, a random sequence of 1's and 0's, strengthened by frequently changing that number and limiting a breach to just a single device. To strengthen this security even further, our fourth line of defense introduces a random data breadcrumb into the security stream. The breadcrumb requires the device being authenticated to execute an action to retrieve a small piece of data that was previously sent and return it to the requesting device along with its authentication request. This introduces a unique multi-device time element into the security method and greatly increases the difficultly of breaching the device's security.

Data sharing: a pillar for success

So far, we have discussed how the S2CT Data Security Model makes it difficult to hack data from individual asset monitoring devices deployed and traveling in the global supply chain by independently protecting each of the devices. The next element of data security that must be addressed is in the cloud. This is probably where the data is most vulnerable or at least most targetable. On the other hand, driven by that vulnerability, this is where most of the security technology is focused with firewalls, passwords, AES encryption, SSL secure links, virtual private network connections, etc. The S2CT Data Security Model does not bring much to this area of security technology and rather depends on the biggest corporations in the world, offering cloud virtual servers and services, to provide these important security technologies. One exception is in the area of data sharing, in our minds, a pillar for success of companies operating supply chain related businesses. Here, S2CT brings a lot to the table, namely, the S2CT Dynamic Secure Data Sharing Network.

S2CT Dynamic Secure Data Sharing Network

We won't describe the intricacies of what and how the S2CT Dynamic Secure Data Sharing Network operates but will touch upon what makes it safe and reliable from a data security perspective. Fundamentally, the Data Sharing Network links two virtual clouds together, when their supply chain interests intersect, and shares data selected by each data owner with the other until their interest-intersection comes to an end. This temporary link is dealt with, from a data security perspective, in much the same way two communicating devices are dealt with in the S2CT Data Security Model.

The two Data Sharing Network clouds are linked, peer-to-peer, through a Virtual Private Network (VPN) connection. The data selected by each data owner is shared with the other using a dual "random-key" encryption model, similar in concept to a Public Private Key pair. Because the keys in the pair are mathematically related, whatever is encrypted with a Public Key may only be decrypted by its corresponding Private Key and vice versa. One key is passed through the peer-to-peer data-connection and the second key through a Data Sharing Security Manager cloud connection. These keys are randomly generated and change over time. The Dynamic Secure Data Sharing Network's operation and deeper details of its security will be covered in another S2CT paper in the coming weeks.

S2CT Data Security Model

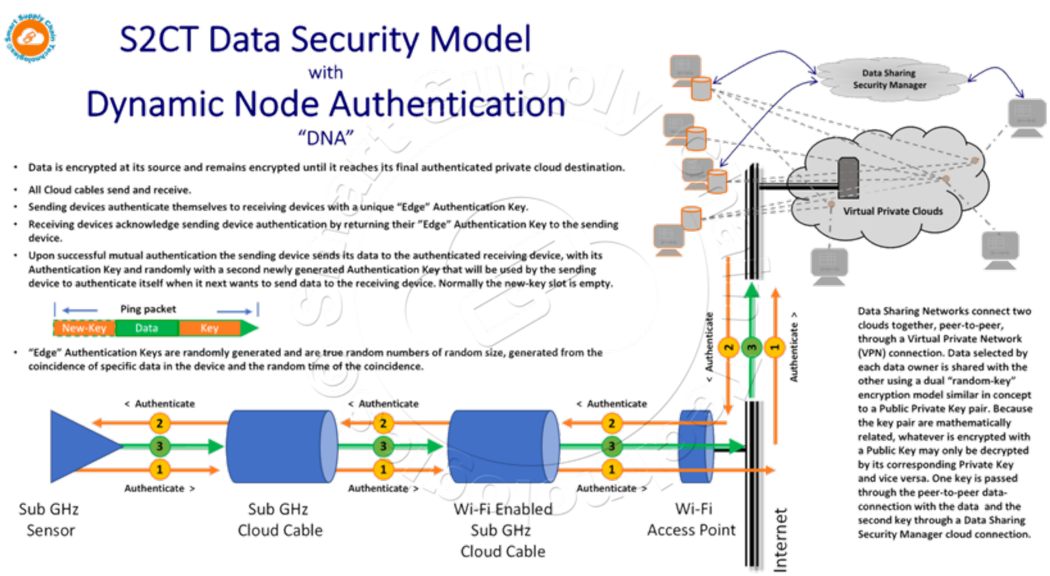


Figure 31

Key Points of the S2CT Data Security Model:

- Strong Data Encryption at the data's source
- Strong device-level random number authentication, coupled with time and action-based data breadcrumbs
- Device-level authentication keys and data breadcrumbs are randomly changed using the random coincidence of device-level events and data
- Only data from authenticated devices is propagated to protect against false data insertion from rogue devices
- Bidirectional device to device and device to cloud authentication
- Cloud to Cloud Data Sharing using data security methods similar to that used by devices for device to device communications

S2CT's intent is to make it very difficult to break an asset's data security and to further ensure that any unlikely break-in only exposes the minimal data of a single device, very low value for high effort and cost! At the same time, we want to ensure that this data security can be successfully implemented on the simplest and least expensive asset monitoring devices, like microcontrollers and Raspberry Pi (*) class Cloud Cables.

AI, IoT, Blockchain, and Robotics for End-to-End Supply Chain Planning, Monitoring, and Management wrapped in Security

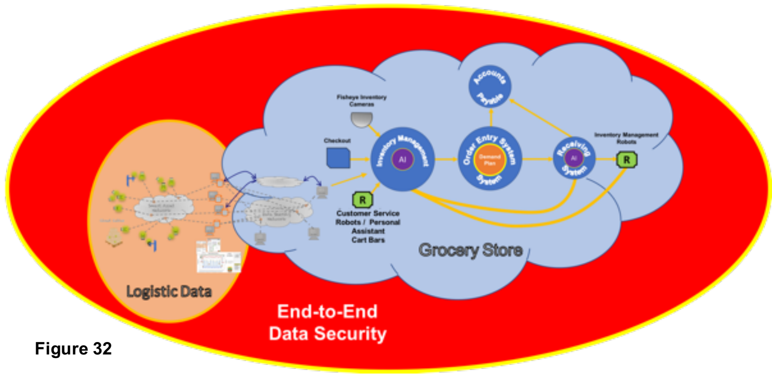


Figure 32

End-to-end supply chain management begins with AI Demand Planning. AI Enterprise Demand Planning helps to set business objectives and daily inventory demand across an entire enterprise with single store resolution. Once the inventory demand requirements are set, each store's Order Entry System places the underlying product orders with multiple suppliers with product, shipping, and delivery details.

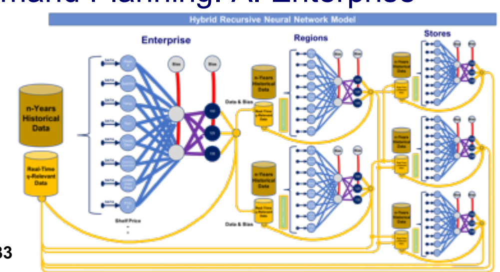


Figure 33

Once an order is placed, the store's Inventory Management System monitors each product's journey through its particular supply chain to ensure that the store meets its Inventory Demand Plan. The Inventory Management System accomplishes this using a secure peer-to-peer data sharing network to dynamically retrieve data, Blockchain-of-Custody blocks and alerts, from the private databases of the logistics companies managing the delivery of products to the store and selected carriers if necessary.

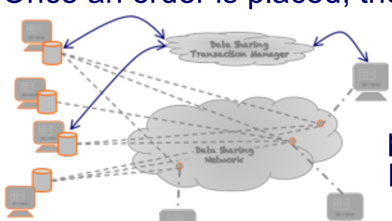


Figure 34

Logistics companies, responsible for the success of the deliveries they are hired by the suppliers to manage, monitor each cargo's progress as it moves from carrier to carrier, with Blockchain of Custody data and alerts when things go wrong, from each carrier.

Each carrier generates its own Blockchain of Custody with an Exchange Verification, EV, when the cargo it delivers to the next carrier is digitally confirmed to match what it received. Match might even mean that cargo ambient conditions during transport were within the specified limits detailed in the shipping order. Carriers will often use IoT devices to monitor and communicate, for their database records and Blockchain blocks, the ambient conditions in their transport cargo area's while moving through their supply chain routes, things like temperature, humidity, CO_2, etc.

Figure 35

The logistics companies use their own AI monitoring software to estimate EV windows and can take several actions when an expected EV doesn't occur within the window. Ultimately, the logistics companies will notify the store when a cargo's delivery is impacted, delayed or even worse. Upon a material impact, the store's Inventory Management System's Second

Source AI jumps in to ensure that the store seamlessly gets the inventories it needs on its shelves.

The store's Inventory Management System's AI "Second-Source" Software resolves delivery impacts and failures with a second source supplier for the impacted products. This can range from full to partial replacement of the impacted order's products, coordinated with the Demand Plan so that the store's "daily" inventory plans go unimpacted and the longer-term plan is smoothed out. The overall-objective is to maintain the store's daily inventory plan and business objectives and thereby the enterprise's plan and objectives.

Once the ordered inventory products are in the store the store's Inventory Management System enters the final Blockchain-of-Custody, with its EV, in its database and takes over monitoring each product to ensure that they get to the store's shelves before their sell-by-date expires. The ideal scenario is a seamless flow of new inventory to get to the store's shelves just-in-time to replace sold products. No shrinkage is the general store mandate.

The store's Inventory Management Robots shepherd the new inventories from the receiving dock into and through the store's stockroom, refrigerated cold-storage units, Fresh Cut and Meat Preparation Areas. Inventory Management Robots continuously report inventory movements and locations in the stockroom area to the Inventory Management System until it departs the stockroom for the store's shelves.

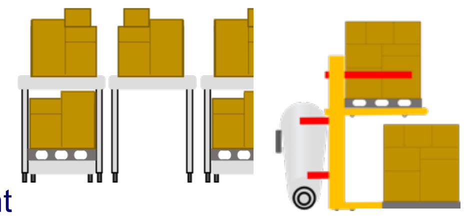


Figure 36

Once on the store's shelves, the products are vigilantly monitored by the store's Inventory Monitoring System utilizing the store's network of Fisheye Cameras and AI inventory image recognition. Customer Service Robotics, like the Personal Assistant Grocery Cart Bar, whose primary mission is to assist and facilitate the customer's shopping experience, can also assist inventory monitoring when required. Finally, all this data and the store's checkout register are utilized to continuously reconcile the store's inventory from receiving dock arrival, to shelves, to departure in a customer's shopping bag.

Figure 37

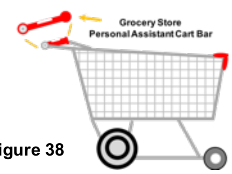


Figure 38

The store continuously orders exactly what it needs, monitors what it orders as it moves through the supply chain until it arrives at the receiving dock, then vigilantly monitors it throughout its final journey through the store to a happy customer. Nothing is misplaced or goes "missing" in the store. Nothing expires before its sold, no shrinkage.

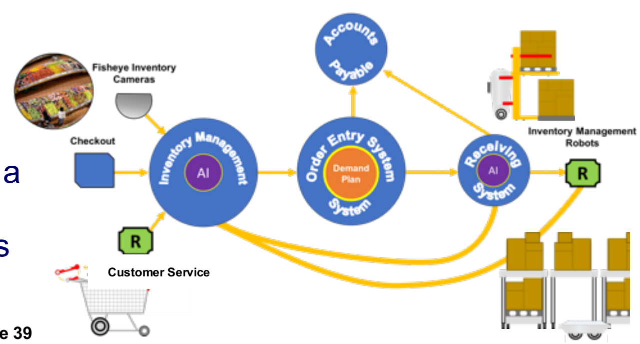


Figure 39

Jim Davis and Eric Lam, Ph.D. are principals at Smart Supply Chain Technologies, Ltd. (jim.davis@s2ct.tech, eric.lam@s2ct.tech)

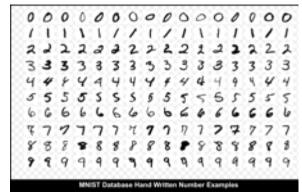
Alejandro Cano is an industry veteran with more than twenty years of experience and currently a Sales Floor Manager for Safeway.

Derek Fong is an industry veteran with more than fifteen years of experience, currently with Target Corporation and was Produce Manager at Safeway when this paper was written.

Footnotes;

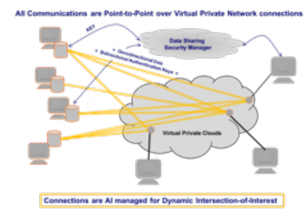
(1) Smart Supply Chain Technologies Ltd., a.k.a. S2CT, is an Asset, Inventory, and Logistics Planning, Monitoring and Management consulting firm. Our solutions, services, and technologies are driven by our leading-edge expertise in "Deep-Learning" Artificial Intelligence (AI), Software Architecture, Blockchain Technologies and Cloud Computing, and over 20 years of experience in building secure IoT networks and devices. We have been using Cloud Architecture, Blockchain-of-Custody, Secure Dynamic Business-to-Business Real-Time Big Data, and Artificial Intelligence to reinvent cost-effective supply chain devices and solutions across the global supply chain.

(2) THE MNIST DATABASE of handwritten digits, Yann LeCun, Courant Institute, NYU, Corinna Cortes, Google Labs, New York, Christopher J.C. Burges, Microsoft Research, Redmond. The MNIST database of handwritten digits, available from this page, has a training set of 60,000 examples, and a test set of 10,000 examples. It is a subset of a larger set available from NIST. The digits have been size-normalized and centered in a fixed-size image. It is a good database for people who want to try learning techniques and pattern recognition methods on real-world data while spending minimal efforts on preprocessing and formatting. http://yann.lecun.com/exdb/mnist/

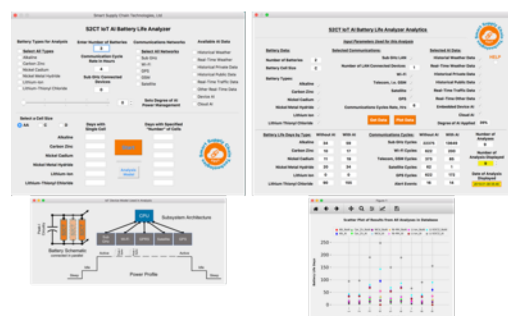


(3) 3Brown1Blue YouTube video series is an excellent resource for understanding neural networks and the mathematics behind them, www.3blue1brown.com/. Michael A. Nielsen, "Neural Networks and Deep Learning", Determination Press, 2015

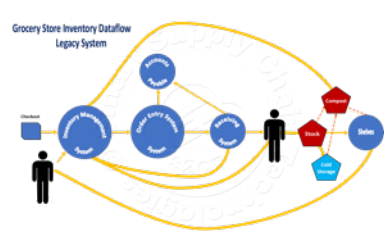
(4) S2CT has developed a "Cloud-Secured", peer-to-peer Data Sharing Network that allows its users to share selected data from their private Asset Management System databases, dynamically, with selected business partners and supply chain stakeholders. S2CT's Data Sharing Network connects two networks, peer-to-peer, through a Virtual Private Network (VPN) connection, selected data is shared based on a successful dual "random-key" exchange, one through the peer-to-peer connection and the second through the Data Sharing Network's cloud security management system. Data is always communicated point-to-point!



(5) S2CT AI Battery Life Analyzer has three components: The Analyzer, the Analyzer Analytics Interface and the related AI Neural Network Code for IoT device integration. The figure pictures the Analyzer and the Analyzer Analytics Interface and popup windows for each. The Analyzer allows the user to select the parameters to be used in an analysis of a Standard Device Model. The Analyzer provides a diagram of the Standard Model in a popup window. The results of each Analysis are saved in an SQLite Database. The Analyzer Analytics Interface provides a method to view results for each analysis run and a scatter plot of all of the data in the SQLite Database for a visual comparison. An advanced version of the Analyzer allows the user to modify the Standard Model. Python code available.

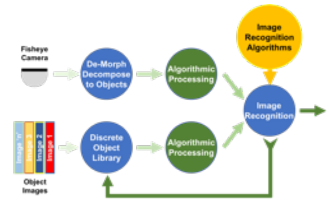


(6) This image illustrates a typical store's legacy Inventory Management System. The collection and inputting of inventory data in the traditional legacy system is enhanced by continuous real-time data provided by the store's AI Fisheye Inventory Cameras and AI robotics. These AI devices transparently collect and send their data to cloud AI software for processing. The AI software processes, and in some cases augments, the data and then enters it into the legacy system in much the same way that a person would. Transparent System Integration from a legacy system's perspective. The Inventory Management and Order Entry perceive and deal with the AI provided data in exactly the same way they would deal with data from another software program or data entered by a person at a terminal. Similarly, the backstage Inventory Management Robot, also transparently connected to its own AI system, for all practical purposes performs its task in the same way a person might, albeit receiving data, instructions, and sending data to the Inventory Management System, continuously, in real-time and without exception.



(7) S2CT joined a team at an Albertsons (*) Grocery Store for 3 plus months in late 2017 working daily in a variety of positions with our co-authors to develop real hands-on insights into the store's operations. S2CT also interviewed personnel at other retail grocery stores during the same period, in some case a number of times, including at Target, Walmart and Costco (*).

(8) Many fisheye cameras have their own integrated fisheye image demorphing software and deliver normalized images to the processing-algorithms for image recognition. This process and "product" image recognition is enhanced at a grocery store by the availability of discrete images of the packaged products the grocery store will stock in its inventory and sell to customers. This discrete library of images is supported by images from suppliers and can be enhanced by the store itself.



(9) The Grocery Store Personal Assistant Cart Bar, GSPACB, can easily be incorporated into a larger personal assistant platform that supports seamless and secure Personal Assistant connectivity and persona-continuity across multiple devices in the home, auto, and the grocery store. Customers can securely communicate with "their" Personal Assistant in their homes to build a shopping list, check and modify the list while driving to the store, and while at the grocery store. In the grocery store context, this is continuous access and control of the grocery list and its history, including receipts for purchases and more.

(10) The Open Platform Specification is an early specification, circa mid-2006, for what data should be shared between supply chain business partners to facilitate the tracking and monitoring of cargo as it moves through a supply chain, private database to private database. Supply Chain partners agree to dynamically

Level-1 Identification	From	To	Level-2 Identification	Level-3 Identification	Level-4 Identification	Carrier	Ship Date	Location	Time Stamp	Sensor 1	Sensor 1 Flag	Sensor 2	Sensor 2 Flag	Misc. 1	Misc. 2	Exchange Verification

share some or all of this data based on mutual business benefits through a secure data sharing network. Related research indicated that these small data packets would address 98% or more of supply chain business partner needs.

(11) A VPN or Virtual Private Network is a method used to add security and privacy to private and public networks, like the Internet. VPNs are most often used by corporations to protect sensitive data. However, using a personal VPN is increasingly becoming more popular as more interactions that were previously face-to-face transactions move to the Internet. Privacy is increased with a VPN because the user's initial IP address is replaced with one from the VPN provider. This method allows subscribers to attain an IP address from any gateway city the VPN service provides. www.whatismyip.com/what-is-a-vpn/

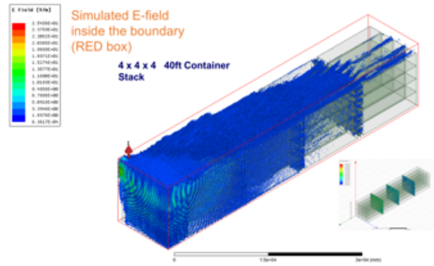
(12) Public-key encryption is a cryptographic system that uses two keys -- a public key known to everyone and a private or secret key known only to the recipient of the message. An important element to the public key system is that the public and private keys are related in such a way that only the public key can be used to encrypt messages and only the corresponding private key can be used to decrypt them. Moreover, it is virtually impossible to deduce the private key if you know the public key. www.webopedia.com/TERM/P/public_key_cryptography.html

(13) Artificial Intelligence is the theory and development of computer systems able to perform tasks that normally require human intelligence, such as visual perception, speech recognition, decision-making, etc.

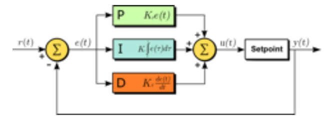
(14) Open Database Connectivity, is a standard database access method developed by the SQL Access group in 1992. The goal of ODBC is to make it possible to access any data from any application, regardless of which database management system (DBMS) is handling the data. www.webopedia.com/TERM/O/ODBC.html

(15) Short for Java Database Connectivity, a Java API that enables Java programs to execute SQL statements. This allows Java programs to interact with any SQL-compliant database. Since nearly all relational database management systems (DBMSs) support SQL, and because Java itself runs on most platforms, JDBC makes it possible to write a single database application that can run on different platforms and interact with different DBMSs. JDBC is similar to ODBC, but is designed specifically for Java programs, whereas ODBC is language-independent. www.webopedia.com/TERM/J/JDBC.html

(16) Sub GHz is a bidirectional communications frequency that is best suited for communications in and around Highly Metalized Environments (HME). The actual frequency selection is driven by the reliability of the communications and the power consumed to undertake them. S2CT has developed an "Open Protocol Standard" called HME Sub GHz, 433 MHz for this purpose. Alternatively, the new Sub GHz 900 MHz Wi-Fi 802.11ah IEEE Standard is being analyzed by S2CT and Hong Kong City University.

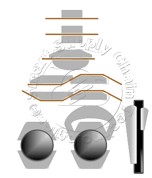


(17) A proportional–integral–derivative controller (PID controller) is a control loop feedback mechanism widely used in industrial control systems requiring continuously modulated control. A PID controller continuously calculates an error value as the difference between the desired setpoint and a measured process variable and applies a correction based on proportional, integral, and derivative terms.



(18) Near-Field Magnetic Inductance is very similar to the technology that Apple, Samsung, and others use for secure wireless payment transactions. Fundamentally, two magnetic fields intersect to form a continuity. In this use model, one field emanates from one device and a second field emanates from a second device. When these fields intersect they form a continuity that allows the devices to communicate with one another. Here, one device provides its ID to a second device. The second device, using some methods, verifies that the ID is authorized for communications and associates it in its communications network for future communications.

(19) The S2CT Universal Enclosure concept is based on a standard core IP-67 enclosure, safely enclosing the core components of an electronic device, that is designed to be further encased in an exoskeleton of arbitrary exterior shape specifically designed to form fit to a targeted application. A Cloud Cable or other Asset Monitor designed to blend into the superstructure of a cargo container so as not to call attention to its presence is an example.



(20) Raspberry Pi is the name of a series of small single-board computers developed in the United Kingdom by the Raspberry Pi Foundation (*).

(21) Node-RED is a powerful tool for building Internet of Things (IoT) applications with a focus on simplifying the ‘wiring together’ of code blocks to carry out tasks. It uses a visual programming approach that allows developers to connect predefined code blocks, known as ‘nodes’, together to perform a task. Node-RED was developed as an open source project at IBM in late 2013, to meet their need to quickly connect hardware and devices to web services and other software. Node-RED has rapidly developed a significant and growing user base and an active developer community who are contributing new nodes that allow programmers to reuse Node-RED code for a wide variety of tasks. Node-RED is part of the JS Foundation, of which IBM is a founding member.

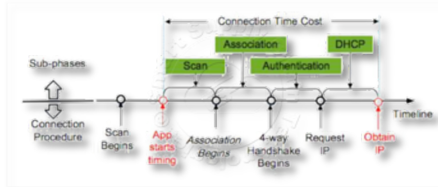
(22) A Visual Embedded Software Library is a library of blocks of programming code that perform specific functions that can be connected together to perform a larger task. A Visual Embedded Library contains blocks of code that use the Application Program Interfaces (API) exposed by device level firmware of various electronic modules, microcontrollers, Wi-Fi Communications, GPS Communications, etc. to perform tasks. Get GPS Position is an example of such a block that when called, sends messages through the GPS Module’s APIs to the GPS module to search for GPS Satellites, retrieve GPS data from each, consolidate the data and return the GPS position.

(23) Programming Pad is a term used to describe a work area on a computer’s display where blocks that represent software functions, get data, encrypt data, store data, etc., are graphically placed and connected together to perform a systematic programming function.

(24) IBM Bluemix (*) is a cloud platform as a service (PaaS) developed by IBM. It supports several programming languages and services as well as integrated DevOps to build, run, deploy and manage applications on the cloud. Bluemix is based on Cloud Foundry open technology and runs on SoftLayer infrastructure.

(25) S2CT Advanced Machine Learning Power Management (AMLPM) is fundamentally software that accumulates operational data from a device’s subsystems over time and uses it to make judgements about using battery energy to perform a specific task, cost versus value. AMLPM might decide to prematurely terminate a GPS cycle based on the time it has taken to find the 1st GPS satellite coupled with the knowledge that the previous GPS data was successfully acquired.

(26) Wi-Fi Cloud Mesh Architecture is the concept that disjoint Wi-Fi Access Points, no actual Wi-Fi field of coverage overlap, can operate as a mesh network by using their common Internet connection to form a virtual overlap. A Wi-Fi node attempting to maintain a persistent connection between disjoint Wi-Fi Access Points uses the same Wi-Fi Access Point "hand-shake" data that was successfully used in its first successful connection to dramatically shorten the Scan, Association, Authentication and DHCP times required when making the second Wi-Fi Access Point connection.



(27) www.washingtonpost.com/world/national-security/fbi-paid-professional-hackers-one-time-fee-to-crack-san-bernardino-iphone/2016/04/12/5397814a-00de-11e6-9d36-33d198ea26c5_story.html

(28) www.scmagazine.com/hackers-compromise-third-party-vendor-amazon-accounts/article/649665/
www.bankinfosecurity.com/crypto-keys-stolen-from-amazon-cloud-a-8581

(29) The Advanced Encryption Standard, or AES, is a symmetric block cipher chosen by the U.S. government to protect classified information and is implemented in software and hardware throughout the world to encrypt sensitive data.

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