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AUTOMATED INVENTORY TRACKING AND VISIBILITY

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ASBSTRACT

Collecting and building an inventory database could be a time-consuming and costly process. Companies in different fields are all seeking strategic, sustainable business practices to improve their inventory tracking and management. Among all that are searching, telecommunication companies are one of the groups that could benefit tremendously from an upgraded inventory tracking system. This thesis examines the potential of integrating cutting-edge technologies into telecommunication companies' inventory tracking process. This thesis includes a series of secondary research that would help Telecommunication Company A, a Fortune 500 company in the telecommunication field, to gain a thorough insight into the current trends of technology advancement and integration in the inventory tracking and monitoring process across the industry. In-depth secondary research benchmarking multiple industry-leading companies in the telecommunication field was conducted for a comprehensive report on the industry trend with technology utilization and integration. A detailed comparative analysis of different cutting-edge technologies was performed to better set the focuses and next steps in the recommendations to Telecommunication Company A.

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Chapter 1

Inventory Tracking Technology

Cost reduction has been one of the strategic business approaches many companies put an emphasis on for their operational development. In the telecommunications industry, business strategies for cost reduction put companies in an especially advantageous position. “While cost management has seen a broad development of concepts and instruments, few transfers to supply chain management have been made so far” (Seuring & Goldberg, 2002). Cost reduction could take place in various areas such as transportation, labor management, procurement, and most commonly, inventory management.

For inventory management specifically, many telecommunications companies are observing inefficiencies in the process of inventory tracking, resulting in excessive site visits, and lack of asset monitoring, which leads to inefficient costs in their supply chain network. There are different ways to cut down costs on inventory tracking, and this thesis will focus on the following steps for further exploration of strategic inventory tracking: identifying the key cutting-edge technologies and tools for inventory tracking, designing a framework and metrics for measuring the optimal technology for a cost-efficient tracking method, and developing the sample model to streamline the process of inventory tracking using the suggested technology.

This thesis will focus on understanding the pros and cons of various cutting-edge technologies by using a multinational telecommunication company as a real-life studying example. The goal is to identify the cost-efficient method to achieve the goal of tracking inventory and monitoring and spacing capabilities regarding the current installed assets as well as to develop a metric to help the company streamline this tracking process.

This thesis will follow such structure: background, research methodology, analysis, and conclusion. The background section will explain the current performance of the telecommunication company in the area of inventory tracking, the current method and technologies being utilized by the company, and the advantages and disadvantages of the current technologies. The methodology section will cover the main approach of the research involved in this thesis including primary research and secondary research. This section will detail the various cutting-edge technologies being utilized in the telecommunications industry, the framework of benchmarking inventory tracking technologies used by similar telecommunications companies, dataset from the example company for supportive study. The analysis section will illustrate results from the primary and secondary research, potential Excel cost analysis models on inventory tracking technologies, designed metrics for process streamlining, the assumptions and recommendations made, risks and mitigations, and key findings. The conclusion section will summarize the recommendations from the analysis section with plans on the next steps for the sample company, especially the relevance of recommended technology, future use by the sample company, and ways the sample company could utilize the key findings and concepts presented in this thesis to streamline and optimize cost management in inventory tracking in the future.

Chapter 2

Background

Company Background

The company this research focuses on will remain anonymous for the purpose of confidentiality agreements. This company will be referred to as Telecommunication Company A. Telecommunication Company A is a Fortune 500 company that specializes in wireless network operation. Their main products and services include mobile phone, home telephone, and Internet services through a variety of devices.

Telecommunication Company A has existing supply chain processes designed with advanced technology utilization including their inventory planning program involving Artificial Intelligence and machine learning to increase level of accuracy on forecasting through statistical models and end-to-end automation. Overall, Telecommunication Company A is standing at the front line for advanced technology and machine integration in their supply chain process, and they have a result-driven goal to develop their inventory tracking and monitoring process.

Project Scope

The Telecommunication Company A has found inefficiency in their inventory tracking process from original equipment manufacturers to regional distribution centers to the cell sites. The current tracking process is a manual-based process, which results in excessive site visits and financial investments when the company requires up-to-date inventory scalability and asset availability status check-in. Given the opportunity to adapt and incorporate cutting-edge technology into the inventory tracking process, the Telecommunication Company A wants to explore further the details of various techniques and devices, hoping to identify one that would offer not only a clear view of the inventory tracking process but also present available information on devices such as desktop for field engineers and site personnel to monitor the asset units, while making sure the option remains cost-effective and is sustainable for long-term business practice.

Introduction of Cutting-Edge Technology

Cutting-edge technology, also known as "bleeding edge" technology, describes technologies that are newly innovated and have not had the chance to entirely develop or mature. Unlike traditional technology devices, cutting-edge technology refers to techniques and technical devices that utilize frontier-level technology. This type of technology is commonly used in the medical, engineering, and automotive industry. Different from any "beta version" or "test version" of any technology or technical devices, cutting-edge technology evolves from the current state of techniques, usually performs at the frontier level of invention and knowledge, and its often viewed as the game-changing piece in the whole puzzle (Molina, n.d.). The new cutting-edge technologies could be broadly categorized into the following categories:

1. Computer vision and the integration of machine learning and graphics
2. Biomedical applications (wearables/sensors/neuroscience)
3. The rust programming language
4. Dedicated machine learning hardware in consumer technology (Bent, 2022)

Using frontier-level knowledge, cutting-edge technology brings a wide range of advantages to companies in different industries. Under the modern business model, cutting-edge technology could potentially expand the company's operation pipeline both vertically and horizontally. Recent examples include the utilization of AI (artificial intelligence) in the automotive industry where the manufacturing facility automates and mechanizes the assembly line to cut down on overhead costs with the decreased need for manual labor (Shaikh, n.d.). When looking at increasing efficiency, upgrading infrastructure, and improving fulfillment accuracy, cutting-edgy technology leads to numerous innovative opportunities such as predicting trendy or seasonal consumer behavior with faster decision-making and deeper insights into consumer purchasing patterns and trends, resulting in higher accuracy in forecasting and order fulfillment planning, which helps companies to establish a competitive role in the market (Shaikh, n.d.).

While cutting-edge technology might have the potential to leverage the business model for companies, the utilization of this revolutionary knowledge comes with limitations and risks. Given that the techniques and devices involved in cutting-edge technology are yet to be introduced as a common tool for the industry, this type of technology often breaks (Molina, n.d.). There are obvious tradeoffs between implementing cutting-edge technology and the risk of a low surviving rate and low guarantee of its effectiveness (Molina, n.d.).

Target Asset Categories

The scope of this thesis is designed around developing inventory tracking and monitoring strategies focusing on network equipment devices for the Telecommunication Company A. The main asset categories the Telecommunication Company A focuses on are as follows:

1. Radios
2. Antennas
3. Cabinets
4. Power Plant
5. Rectifiers
6. OVP (overvoltage protection)
7. Upconverters
8. Routers

The main characteristics of the equipment are that the devices vary in size, typically shipped in units (boxes, pallets, etc.) with large quantities, and “roughly around half a million pieces of equipment will be part of scope on an annual basis” (company presentation). Besides the complex characteristics, these network equipment devices obtain a close-loop life cycle as the devices will be recycled back to the company’s DC once they reach the end of their useful life.

Current Inventory Tracking Process

The current process for network equipment logistics and the life cycle is as follows:

1. OEM (original equipment manufacturer) ships device asset to the company’s DC (distribution center) via over-the-road transportation
2. The company’s DC receives and stocks up network equipment units, create MR (material requisition) report, and pulls asset for site delivery
3. Asset units are delivered at sites for installation and equipment activation

4. Site personnel evaluate, track, and monitor equipment utilization and performance under SLA (service-level agreement)
5. Once the equipment reaches the end of its life cycle, the asset unit will be de-installed and send back to the company’s DC for remanufacturing and recycling

Through this inventory tracking system model, Telecommunication Company A is able to keep up with the available units of the asset on sites. However, the downside of this model is its labor-heavy nature—the required manpower in this process has created an unavoidable ceiling on the accessibility and flexibility of the inventory monitoring oversight. To cultivate an in-depth analysis, secondary research will be conducted with benchmarking on similar telecommunication companies as well as feasible technologies for further development.

Chapter 3

Methodology

Benchmarking Telecommunication Companies

Telecommunication Company A recognizes that their current inventory tracking system provides a thorough update on available units on the asset, but the tradeoff of this manual process has created an excessive cost for extra labor units and site visits. To further understand the full particulars of the inventory tracking process in the telecommunication industry, benchmarking on similar companies will provide Telecommunication Company A with some useful knowledge and insights on the strategies and technology used by other telecommunication companies in their inventory management process.

The key factor in selecting benchmarking subjects is to identify companies that offer similar products and services compared to Telecommunication Company A. The selected pool of telecommunication companies for benchmarking is as follows:

Benchmarking Company A

Benchmarking Company A is an American multinational telecommunication holding company that provides telecommunications, media, and technology services. The company offers wireless communications, data/broadband and internet services, and other network services. The company also develops and produces feature films, television, and gaming content, in both physical and digital forms (GlobalData, 2023). As of 2023, the estimated net worth of Benchmarking Company A is around $132.69 billion.

Benchmarking Company B

Benchmarking Company B is a telecommunication company that offers wireless services and a host of other services including voice, text messaging, and data communications to their customers. The company also carries out the distribution of a wide range of mobile phones, wearables, tables, and other accessories from established vendors (GlobalData, 2023). As of 2023, the estimated net worth of Benchmarking Company B is $175.47 billion.

Benchmarking Company C

Benchmark Company C is a subsidiary part of an online retailer and web service provider company. Benchmarking Company C specializes in cloud computing services, offering a wide range of cloud infrastructure services including computing, storage, developer tools, virtual reality, robotics, game tech, and other front-end technology services. The company serves automotive, digital marketing, telecommunications, oil and gas, power and utilities, and other organizations (GlobalData, 2023). As of 2023, the estimated net worth of Benchmarking Company C is $80 billion.

Benchmarking Company D

Benchmarking Company D is a telecommunication company that specializes in Internet of Things (IoT) systems. The company centers its services around IoT-based sensors and software to provide connectivity, security, GPS tracking, and location-based service. The main products of Benchmarking Company D include ConnectivityPro, Position Logic, and Security

Pro (GlobalData, 2023). As of 2023, the estimated net worth of Benchmarking Company D is $0.09 billion.

Benchmarking Company E

Benchmarking Company E is a provider of IoT and cellular wireless solutions to the machine-to-machine (M2M) and connected device markets. The company specializes in embedded wireless modules, embedded broadband solutions, and IoT connectivity services to original equipment manufacturers (OEM), and wireless gateways and routers for commercial and industrial purposes. The company also offers cloud services for device management and enables end-to-end applications (GlobalData, 2023). As of 2023, the estimated net worth of Benchmarking Company E is $1.2 billion.

Given that these five companies all have similar products and services compared to Telecommunication Company A, this research will focus on identifying the inventory tracking tools and systems these companies are currently operating with, and analyzing the pros and cons of those tools and systems to further build up recommendations for Telecommunication Company A.

Benchmarking Popular Cutting-Edge Technologies

One overarching objective of Telecommunication Company A is to identify one cutting-edge technology that would help them better track inventory units as well as monitor their spacing capability regarding the installed assets in a cost-efficient, sustainable business practice. Telecommunication Company A has an existing Fleet Tracking system that utilizes a cellular connection to transmit data but are powered through a vehicle's on-board diagnostics (OBD) system (Lin, Dugan, Sheybani, Krzysztofowicz, Miller, & Powell, 2020), which limits the vehicle types that these trackers are compatible with.

With this goal embedded, identifying popular cutting-edge technology as well as assessing their functionality and feasibility will provide Telecommunication Company A some useful information and insights to pick the ideal option. The selected technologies are as follows:

1. IoT sensors & detectors
2. Active RFID (Radio Frequency Identification)
3. Passive RFID (Radio Frequency Identification)
4. Robotics
5. Drones

This is not an exclusive list of technologies that are used by companies for inventory tracking; rather, these technologies for networks and devices are relatively popular in the industry.

Metrics and Measurements

To effectively and successfully identify the ideal technology that meets the need and objective of Telecommunication Company A, the following factors will be taken into consideration in measuring and assessing the functionality and feasibility of the technology stated in the previous section:

1. Functionality

2. Advantage

3. Disadvantage & Limitations

4. Scalability

5. Ease of Use & Ease of Implementation

After conducting secondary research on the directions listed above, an outline of key findings and comparative analysis will be included in the analysis section to help Telecommunication Company A to better identify the ideal technology for inventory tracking and monitoring feasibility.

Chapter 4

Analysis

Benchmarking Findings

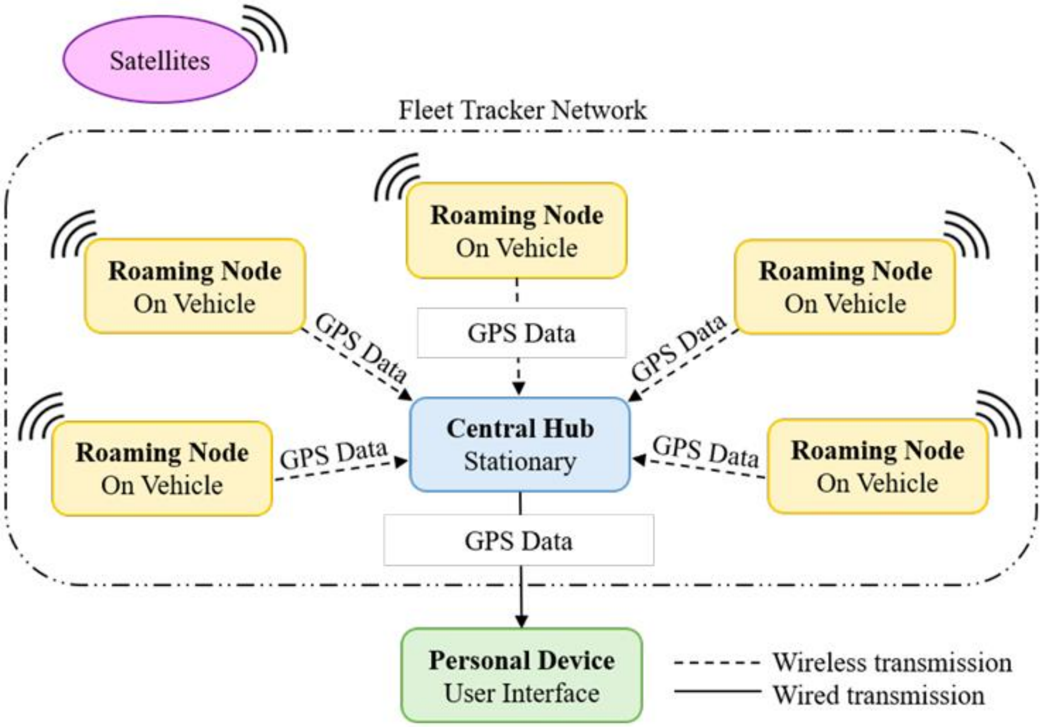
The following results identify and explain the current inventory tracking and monitoring tools that the five similar companies (identified in the previous section) utilize in their networks.

Benchmarking Company A – Fleet Tracker and Asset Tracker

Benchmark Company A utilizes a combination of fleet tracker and asset tracker to track and monitor their inventory. The system operates on a single web-based management portal based on advanced GPS tracking software and IoT devices to track vehicles and assets in near real-time.

A Fleet Tracker system is a network of vehicle-mounted and solar-powered roaming nodes, which acquire GPS data and wirelessly transmit this data to a central hub using LoRa-based network connections (see Figure 1). The central hub processes this data and displays vehicle locations on a real-time and interactive map (Lin, Dugan, Sheybani, Krzysztofowicz, Miller, & Powell, 2020). Commonly, tracker assets are heavily utilized in school bus tracking, but they can be expanded to other tracking applications such as trucking transportation systems.

Figure 1. High-Level Diagram of Fleet Tracker Network



The specialized system Benchmarking Company A operates with, Equipment and Machinery Solutions (EAMS), uses IoT technology to exchange data between the equipment being tracked and a cloud management platform. The equipment has telematics hardware that could be built-in by the OEM, or it could be an attached device. This system is easily accessible through multiple platforms such as a general website page, a designated mobile application, or both at the same time, which provides easy access to asset status in real-time.

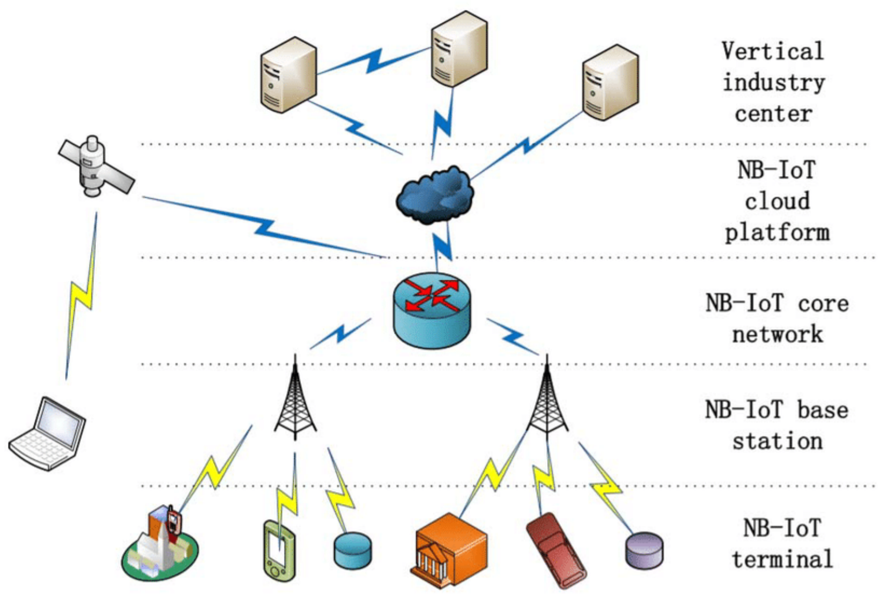
Benchmarking Company B – NB-IoT

Benchmarking Company B utilizes a Narrowband Internet of Things (NB-IoT) network to achieve a far-reaching and thorough asset inventory tracking system.

Narrowband Internet of Things (NB-IoT) is a standards-based low power wide area (LPWA) technology developed to enable a wide range of new IoT devices, system capacity and spectrum efficiency, especially in deep coverage (GSMA, 2017). The NB-IoT network has been designed to offer extended coverage compared to the traditionasl GSM (Global System for Mobile Communication) networks (Svetlana, 2016), resulting in popular adaptation and application in different fields such as consumer goods tracking, agricultural environment monitoring, pollution tracking, and HVAC (Heating, Ventilation, and Air Conditioning).

Compared to the traditional method of inventory asset tracking where the tracking and monitoring activities take place within LTE-M (Long-Term Evolution for Machine) network, NB-IoT is a level-up option for a cost-effective, widely ranged tracking network with fast communication connectivity (Svetlana, 2016). The benefit of adopting NB-IoT schemes include "facilitat[ing] the utility grid system to monitor and control field devices remotely (see Figure 2), resulting in promoting the power system to operate efficiently and economically" (Al-Rubaye, Rodriguez, Fragonara, Theron, & Tsourdos, 2019).

Figure 2. NB-IoT Network

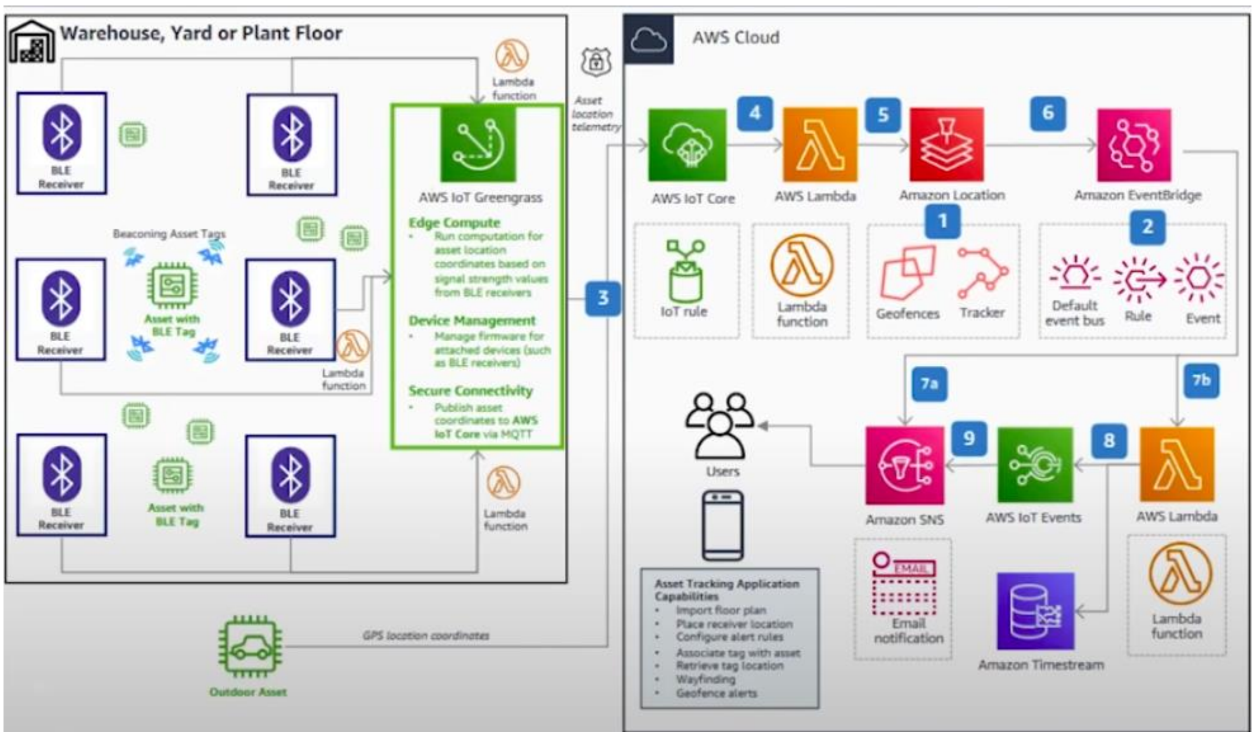


Benchmarking Company C – Bluetooth Receiver and IATM

Benchmarking Company C utilizes various technologies for inventory management, predominantly the Bluetooth receiver system for geo-location tracking and IATM (Intelligent Asset Tracking and Management) for asset visibility.

The Bluetooth receiver system is a strategic method for asset unit tracking within a specific, closed space that requires a level of layout structure, such as inventory warehouses. Within Benchmarking Company C's warehouse, there are Bluetooth receivers installed in different corners recording and monitoring the units of asset within a program-applied range. Once the inventory units arrive at the warehouse, Bluetooth receivers will set up signal connections by detecting the barcode located on the packages from a far distance; through this connection, Bluetooth receivers could record and report the geocoordinates of those units to the IoT core (the main mechanism for IoT network) constantly for warehouse personnel to check and monitor the inventory level. The way Bluetooth receivers create accurate geocoordinates for asset units in the warehouse is by comparing the connection percentage with different inventory units to paint the estimated geolocation inside the warehouse. Once the geolocation of inventory units is set up, Benchmarking Company C's engineers could check on the inventory unit availability and its correlated location by sending the coordinates to the trackers and pulling up the inventory details (see Figure 3).

Figure 3. Inventory Tracking with Location Services Overview

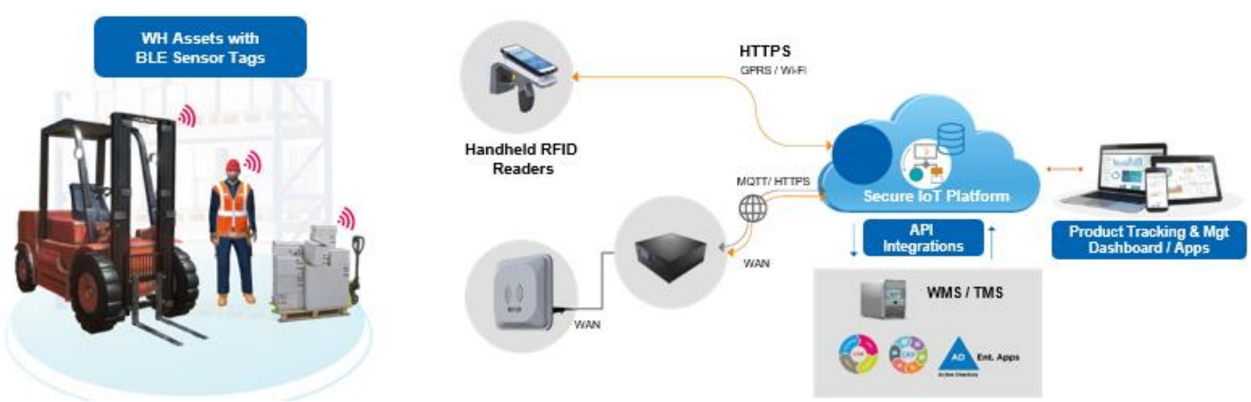


Other than the Bluetooth receiver system, Benchmarking Company C also has a partnership with HCLTech, a multinational company specializing in information technology services and digital technology transformation. HCLTech provides IATM (Intelligent Asset

Tracking and Management) to Benchmarking Company C as a solution to improve operational efficiency by detecting asset tracking capability and asset visibility.

The IATM solution evolved from an RFID-based solution to track assets and manage inventory for end-user computing (EUC) devices at an enterprise level (Mathur, Tripathi, Banerjee, and Sharma, 2021). The key focus of IATM: Smart Warehouse solution aims to "improvise the key challenges faced by warehouses in tracking inventory visibility, optimizing current warehouse processes, and reducing safety incidents by tracking Material Handling Equipment inside warehouse premises" (Mathur, Tripathi, Banerjee, and Sharma, 2021). The IATM involved in this process has been integrated with SAP Extended Warehouse Management (EWM) and thus grants IATM the ability to use tracking technologies such as RFID and BLE (Bluetooth Low Energy) to collect information. Through this system, the end users are able to track and monitor asset status on product tracking and management dashboard and mobile applications (see Figure 4).

Figure 4. IATM Smart Warehouse Overview



Benchmarking Company D – Critical Asset Management

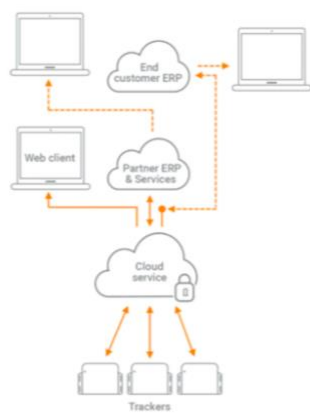
Benchmarking Company D explains its inventory tracking service, Critical Asset Management (CAM), with a case study on a global service group specializing in medical and laboratory equipment. The service group wanted to improve customer satisfaction by remodeling their order fulfillment structure to achieve the goal of timely delivery for medical instrumentation from and to client sites. Benchmarking Company D evaluated this service group's performance and pinpointed the issue in their order fulfillment process: there is an overall lack of visibility that causes equipment damage, order fulfillment delay, and inventory disruption. Moreover, the lack of constant shipment visibility and an effective measurement on estimated arrival time provided by the traditional RFID gave no internal or external visibility on the medical equipment.

To mitigate the lack of visibility in the process, Benchmarking Company D created the CAM system to leverage a GPS device with condition monitoring capabilities that could attach to the instruments to enable tracking and gain visibility anywhere. Devices and technologies involved in CAM include advanced trackers, sensors, algorithms, cloud services, and more (see Figure 5).

Figure 5. Critical Asset Management Sample Kit

The process of CAM is as simple as setting up trackers at infrastructure sites for cloud service connection, and the final stop is reaching end-user applications through End Customer ERP (Enterprise Resource Planning) (see Figure 6).

Figure 6. Critical Asset Management Overview



Benchmarking Company E—Combination of Software Application and BLE

Benchmarking Company E specializes in managing cargo asset tracking processes using their solution called Acculink. Through using IoT networks, Benchmarking Company E designs wireless tracking solutions for all types of cargo such as containers, bins, crates, and heavy equipment. The tracking solutions could apply not only to cargo asset tracking but also to general, pharmaceuticals, electronics, food and produce, and large-sized equipment.

One part of Acculink is the software application focusing on tracking and monitoring shipments in real-time. The application monitors the temperature, vibration, shock, light, and motion, to paint the picture for customers in terms of the order shipment status. Another part of Acculink is the integration of BLE (Bluetooth Low Energy) sensors monitoring environmental conditions like “temperature, humidity, shock, vibration, light, and motion. This enables shippers to know the location of their cargo and other assets in near real-time – enabling quick and decisive action should a change in scheduling, an event of loss or theft, or an update in state of being occur” (Ague, 2021).

Benchmarking Technologies Findings

Internet of Things Sensor

Internet of Things (IoT) describes a network with digital devices, mechanical machines, subjects, and other things that are “provided with unique identifiers (UIDs) and have the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction” (Gillis, 2022). The primary objectives of IoT sensors include sensing critical information from the external physical environment, sampling internal system signals, and obtaining meaningful data from sensor data to perform decision-making (Krishnamurthi, Kumar, Gopinathan, Nayyar, and Qureshi, 2020).

IoT application is commonly used in the supply chain process tracking field. In logistics container tracking, the process usually "relies on RFID tags which are attached to the containers, boxes, and pallets included in the shipment and then read at a number of points along the way" (Gillis, 2022). IoT-based inventory tracking mechanism has the power to monitor asset units in real-time and it could check for "[product] categories, product types, zones, facilities, and geographies, [which] providing better insights into key metrics such as inventory utilization and warehouse space utilization" (Prijic, 2020).

While looking at the advantages IoT sensor brings, it's important to think about scalability. Measuring the scalability of IoT sensors is simply the process of IoT going from the newly developed prototype to real-time production. It's important to scale as many manufacturing and production sites have the intention to implement IoT devices at a large scale. When designing and measuring the scalability of IoT devices, businesses run into various challenges during the process. The most popular roadblock to implementing IoT devices is cellular coverage and connectivity, which requires companies to make strategic decisions in the following categories:

1. Radio access technology
2. IoT protocols and standards
3. SIM provider MNO (Mobile Network Operator)
4. Roaming partner MNOs (Particle, n.d.)

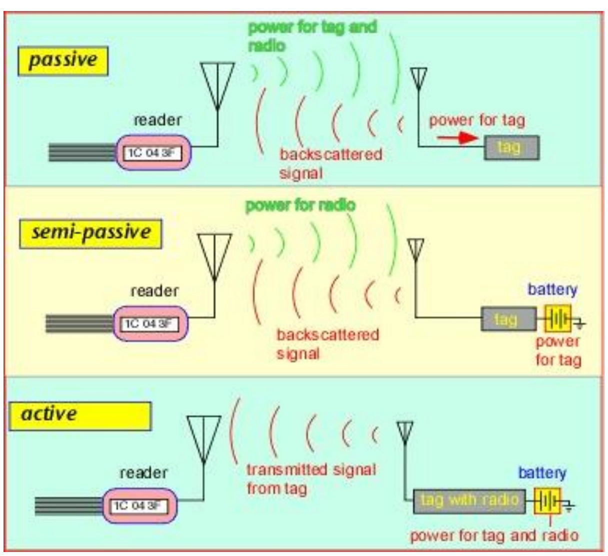
Overall, the IoT sensor is a popular option for inventory tracking and monitoring; it is also a financially sustainable option for companies that are thinking about using it on a large scale. On average, the cost of an IoT sensor could be as little as $0.38 per piece. While the connected devices could help businesses to track asset units in real-time, IoT sensors could also cause inefficiency when the inventory unit is at a large scale.

Active RFID vs. Passive RFID

RFID (Radio Frequency Identification) technology utilizes radio waves to identify and track tags that are attached to products and objects. The tags contain "transponders that emit messages read by specialized RFID readers" (Weinstein, 2005) where identification numbers are stored.

RFID tags are split into two categories—active RFID and passive RFID—depending on the source of power. Active RFID tags "contain their own power source, usually an on-board battery" (Weinstein, 2005); whereas passive RFID relies on power from external source and signal (see Figure 7).

Figure 7. Active RFID vs. Passive RFID



Since they have their power source, active RFID tags convey a stronger signal with a wider range to reach. The on-board battery makes them larger in size and more expensive, which gives them the competitive advantage of tracking large items over long distances. The on-board battery setting also grants active RFID the feature to operate at a high frequency – "commonly 455 MHz, 2.45 GHz, or 5.8 GHz… readers can communicate with active RFID tags across 20 to 100 meters" (Weinstein, 2005), which is around 65 to 330 feet. On average, active RFID tags cost $15-$20 USD per piece.

Unlike the pricy active RFID tags, passive RFID tags could cost as little as $0.20 per piece. On top of the low cost, passive RFID is much smaller than active RFID in size due to not having its own power board, which leads to its two disadvantages: small storage to read complex information and a shorter coverage range.

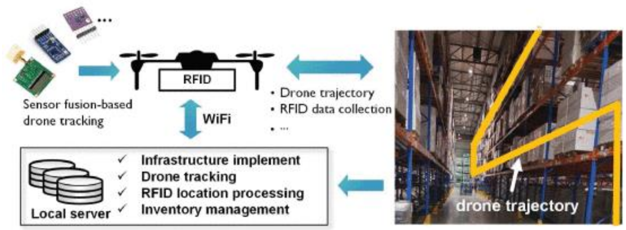
Robotics and Drones

Bringing robotics into the inventory tracking process is not a new thing in inventory tracking. The sight of first robot used in the supply chain is by George Devol who filed the first robotics patent in 1954; the robot was able to move materials for a couple of feet (Logiwa, 2023). The application of robotics in warehouse inventory management depends on three primary aspects: the depth of machine learning, the capability of sensors and trackers, and WMS software (Logiwa, 2023). McKinsey & Co. once conducted a study on the adoption of AI in business practice, and the research study found that "the transportation and logistics industry stands to gain 89% incremental value over time through AI adoption" (Logiwa, 2023).

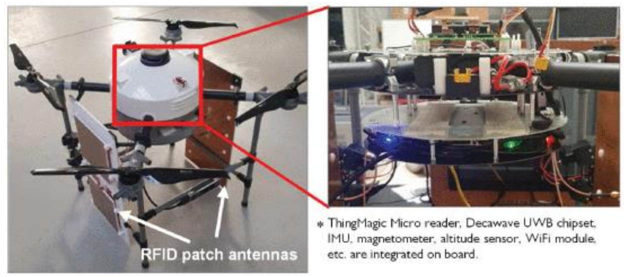
One example of using robotics in warehouse management is the study on UHF-RFID (Ultra-High Frequency RFID) robots for real-time inventory and localization monitoring system. In the study presented at the 12th International Conference on RFID Technology and Applications, the research group talks about examing the development of automated devices in warehouse inventory system using an autonomous robot with an RFID system embedded to measure the capability of the robot leading itself inside the warehouse. The UHF-RFID robot collects phase data from tags on a shelf to develop a Kalman-based algorithm for self-localization; once the data received from the tagged items to be located matches with the parametric data collected by the robot, the study could proceed to further actions with the confidence that this RFID-embedded robot is able to collect, translate, and locate items from the shelf (Bernardini, Motroni, Buffi, Nepa, Tripicchio, D'Avella, Del Col, and Salvatore, 2022). As a result, the UHF-RFID robot is able to identify several tags and locate them on the shelf.

Though introducing robotics with UHF-RFID to warehouse inventory management seems to be a relatively innovative step, the industry has also set the vision on utilizing drones. A drone-based RFID system (see Figure 8) is the design using a drone with a UHF-RFID reader and antennas mounted to file along the planned trajectory for inventory information collection (Mizuno, Miwa, Naito, and Ehara, 2023).

Figure 8. Drone-Based RFID System Set-Up



(a)



(b)

Drone-based RFID is considered an ideal solution to leverage the inventory tracking process to the next innovative stage, especially with its low operation cost, low labor cost (close to zero once the devices are one hundred percent operating on their own), low learning curve; however, there are technical challenges when everything goes live. The research team encounters errors such as drone tracking errors (resulting in the wrong phase-based RFID positioning coordinates) and the phase center effect (resulting in inaccuracy in the center phase due to the shift in angles).

Comparative Analysis

Given the major focus of Telecommunication Company A is to identify one key cutting-edge technology that would help them track inventory units on sites as well as monitoring and spacing capability, Table 1 below presents a side-by-side comparative analysis of the key technologies with measurements identified in the previous chapter.

Table 1. Comparative Analysis on Cutting-Edge Technologies

Criteria	IoT Sensors	Active RFID	Passive RFID	Robotics Integration	Drone Integration
Functionality	Share the sensor data through connecting to the IoT Core cloud	Radio wave-based tracking technology; local power board embedded	Radio wave-based tracking technology; powered from the signals of external readers	Device connected to (embedded or coded) RFID tags for further usage	Device connected (or attached) to RFID tags for further usage
Advantage	Provide real-time data; remote monitoring, does not require physical personnel; time-saving process	Wider cellular coverage; stronger connection over long distances	Lower cost than active RFID; economical; more ideal for sizing and spacing	Huge saving on labor cost; time-saving performance; high quality and accuracy	High quality and accuracy; inventory unis and spacing capability monitoring remotely
Disadvantage	Small cellular coverage and connectivity; security and privacy concerns; inefficiency in working with large-scaled data	Relatively expensive; security	Smaller cellular coverage; needs a reader for power board	High material and operation cost; complex RFID compatibility; high long-term investment cost	No universal RFID standards compatibility with drones across the industry;

		and privacy concerns			potential data delay
Scalability	Feasible on inventory tracking; might need to scale up the quantity of IoT sensors or invest more in the sensor features if thinking about a large amount of project sites (70,000+)	Would be a competitive option for remote monitoring over a long distance; need to invest more on data privacy and protection	A suggested option if budget is the main concern; additional material costs such as battery needed to support the network	A high-level advanced technology; a long-term financial investment and experiment; would recommend if budget is not a main concern	A long-term test trails and financial investment; need time to test out the accuracy as well as training site personnel for applications
Ease of Implementation	Need standardized system that will be compatible with the IoT sensors; typically a 18-24 months implantation process with high risk of failure	Requires testing and system development; typically a 6-12 months process for one site's implementation	Requires testing and system development; typically a 6-12 months process for one site's implementation	Need to set the scale of equipment that will be replaced by robotics; factor training time with site personnel	Huge financial investment; need to factor training session as well as the scale of equipment/labor being replaced

Limitation and Next Steps

The main limitation of this research was the available information and details on benchmarking companies' specific strategies and technologies in their inventory tracking and monitoring process. Many industry-leading companies are willing to share the surface-level overview of the company's strategy and performance in inventory management, minus the specific architecture diagram behind the scenes. It was estimated that the benchmarking companies are all utilizing the stated cutting-edge technologies at full capacity at their project sites. In reality, it is expected that some of the benchmarking companies are still in their development phase and implementation planning phase with the new technologies.

In addition, this research emphasizes more on the in-depth industry trends analysis and companies' portfolio on cutting-edge technologies utilization from a business standpoint; there is less emphasis on the scientific explanation involved in the cutting-edge technologies from the engineering standpoint.

It is recommended that Telecommunication Company A should look into the scale of inventory tracking technology upgrade, whether it is the specific amount of project sites that they want to start revamping the technology utilization or the ideal timeline for cutting-edge technology implementation at full capacity.

Chapter 5

Conclusion

Based on the industry benchmarking and an in-depth secondary research on the popular cutting-edge technologies, it is recommended that Telecommunication Company A would start their investment with RFID technology as the main focus, with the possibility of integrating active RFID into IoT sensors for next-level inventory tracking and monitoring development.

Although many companies are implementing newer forms of technology such as robotics, self-driven forklifts, and drones, RFID tags are an inseparable and complementary part of a technology upgrade and advancement in warehouse inventory management. RFID serves as a jumping board for next-level development including integrating frontier-level devices into the inventory management system.

Next, it is recommended that Telecommunication Company A identify specific equipment at a designated project site for RFID implementation as a test trial to measure the feasibility and the improvement RFID brings to the inventory tracking and monitoring process, if any. If Telecommunication Company A could observe a significant change in the inventory management process, whether the change being a reduction in cost or an increase in process efficiency, this research's recommendation could be adopted.

Finally, similar telecommunication companies could find this research helpful in understanding the industry trends and current climate in cutting-edge technologies and inventory tracking systems. Companies can gain a better understanding in comparing different devices and networks for different results, aiming for an increase and upgrade in their inventory tracking and monitoring process.

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ACADEMIC VITA

Yuwuxia "Chrisly" Li

EDUCATION

The Pennsylvania State University **University Park, PA**
Schreyer Honors College | Smeal College of Business *May 2023*
Bachelor of Science in Supply Chain and Information Systems | Minor in Management and Information Systems

WORK EXPERIENCE

The Joshua Tree Group **Franklin, TN**
Supply Chain Intern *June 2022 — August 2022*
- Collaborated with team members to develop SKU Audit database with over 10,000 datapoints from across 6 project sites for a multinational retail corporation to help automizing inbound and outbound processes for potential efficiency growth and cost reduction
- Accelerated auditing productivity and increased auditing efficiency through developing efficient data input methods
- Gained hands-on experience in order fulfillment process such as "Pick to Belt"; trained to build labor standards and preferred methods for productivity measurements and potential efficiency growth on the floor
- Delivered mentoring sessions to warehouse workers through instructing preferred methods in the process to them for utilization growth

Rockwell Automation MOQ Project **University Park, PA**
Supply Chain Analyst *August 2021 — January 2021*
- Sourced and organized over 3000+ raw data on order history from Excel containing material details, production quantity at plants, receipt, and shipment quantity to customers, to identify the optimal minimum order quantity for top orders at Rockwell Automation
- Built a side-by-side Excel model for data comparison to identify the efficient and cost-saving minimum order quantity with suppliers
- Identified and made recommendations to remove >40% excess orders with inefficient order quantity over the period of 12 months

Smeal Business Career Center **University Park, PA**
Career Service Intern *August 2021 — Present*
- Facilitated 70+ individual workshops, one-on-one coaching sessions, and training to undergraduate students about career marketing, job search process, and effective strategies on utilizing online tools for a comprehensive career recruitment process
- Devoted over 80 hours of consulting services to business students including interview skills, resume review, cover letter, LinkedIn branding, and other helpful job-searching tools and advice to best assist students to achieve and excel in the recruitment process

LEADERSHIP EXPERIENCE

Sapphire Leadership Academic Program **University Park, PA**
President *December 2021 — December 2022*
- Appointed to serve as the president of the academic program including 200+ members that represent the top 5% of the business college
- Led an executive board of 17 members to foster a career-driven, community-serving, and D&I-focused environment in the program
- Collaborated with co-president to execute leadership initiatives to expand the program's quality to maximize member learning potential
- Assisted the implementation of college-wide events opening to 5000+ students promoting ethical leadership and community service

Communications Captain *January 2021 — December 2021*
- Monitored Mailchimp email platform and obtained effective communication through sending out weekly emails to 200+ members
- Revised strategic marketing plan and implemented new marketing materials on the social media platform, resulting in an increase of 50% in account reach, 85% in account followers, and 120% in account engagement, on Instagram

Nittany Lion Consulting Group **University Park, PA**
Vice President of Organizational Engagement *December 2021 — December 2022*
- Coordinated 10+ programs per semester to enhance NLCG culture and value while fostering an inclusive community for 80+ members
- Operated complex Excel system through integrating multiple data elements for performance analysis and improvement on engagement

Penn State SBU Project Manager *August 2021 — December 2021*
- Assisted the Penn State Nittany AI Alliance outreach program in creating integrated communication strategies to create innovative and effective strategies targeting undergraduate students in the field of Artificial Intelligence and AI's connection with the UN SDGs
- Generated reports on Excel and PowerPoint to analyze demographics and target markets among undergraduate students at Penn State while optimizing communication and introducing 10 new marketing initiatives to project an increase in student engagement by 50%
- Composed a 33-page research deliverable with multiple data integration, detailed analysis, and recommendations for the client

Penn State Residence Life **University Park, PA**
Resident Assistant *August 2021 — Present*
- Served as a mentor and advisor for 54 first-year students to start a new chapter of life and transition to the campus smoothly and safely
- Collaborated with fellow RAs to implement programs and received programming award for creating and supervising an inclusive community and educating first-year students about ongoing social issues, social justice, and raising awareness in the college campus
- Enforced College and Campus Living policies to promote an equal and safe residential environment on a weekly basis; practiced University Policy protocols, quickly adapted and performed the responsibilities and duties in solving emergent situations

HONORS/SKILLS

Honors: *Sigma Chi Mu Tau Supply Chain National Honor Society*; Penn State SCIS BUSGE Scholarship
Technical: Course-Certified in Python, SQL & R; Proficient in Microsoft Excel, PowerPoint, Word; WordPress; Mailchimp
Language: Fluent in English, Native in Mandarin