

# Mobile Computing Alternatives for Manufacturing Warehouse Operations

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## Introduction

This paper looks at the advantages and disadvantages of three alternate architectures for implementing warehouse tracking systems in a manufacturing environment.

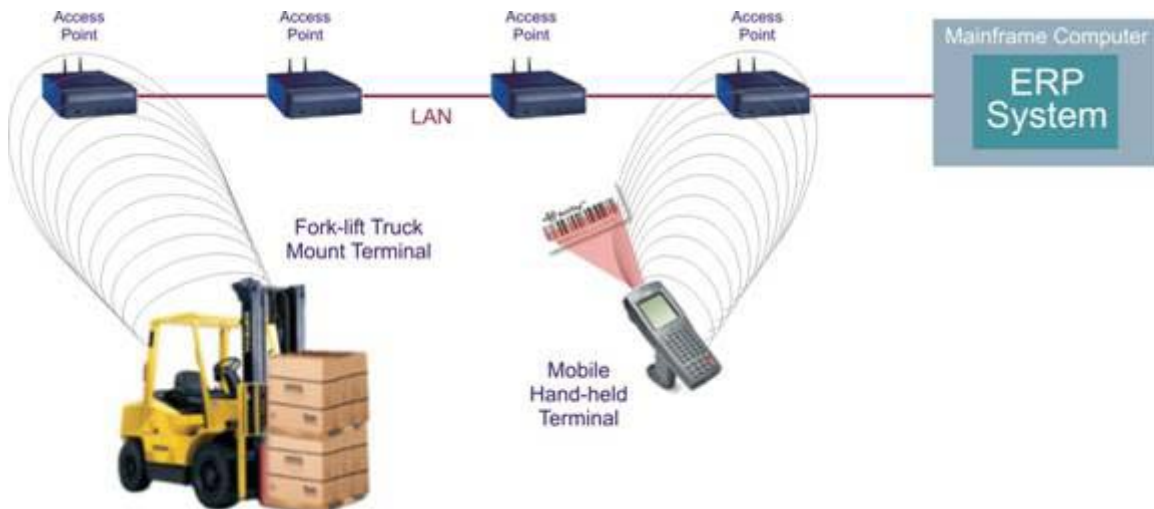
## Three Alternatives

There are three alternate configurations possible when there is a need for mobile computing in a warehouse for receiving, put-away, picking, and shipping operations. These are:

1. Wireless Terminal Operation
2. Batch Operation
3. Wireless Store-and-Forward Operation.

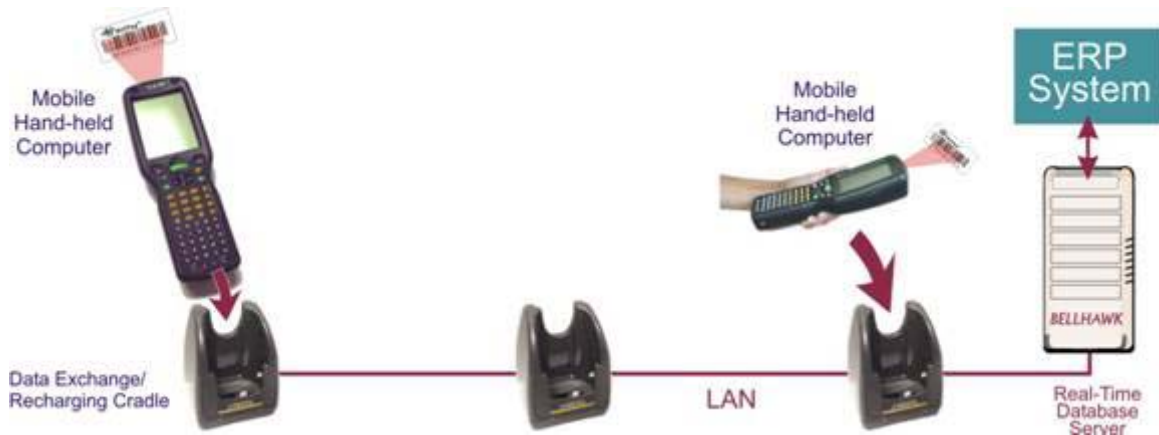
These systems are typically implemented with either mobile hand-held computers or with fork-lift truck mount computers.

In an wireless terminal operation:



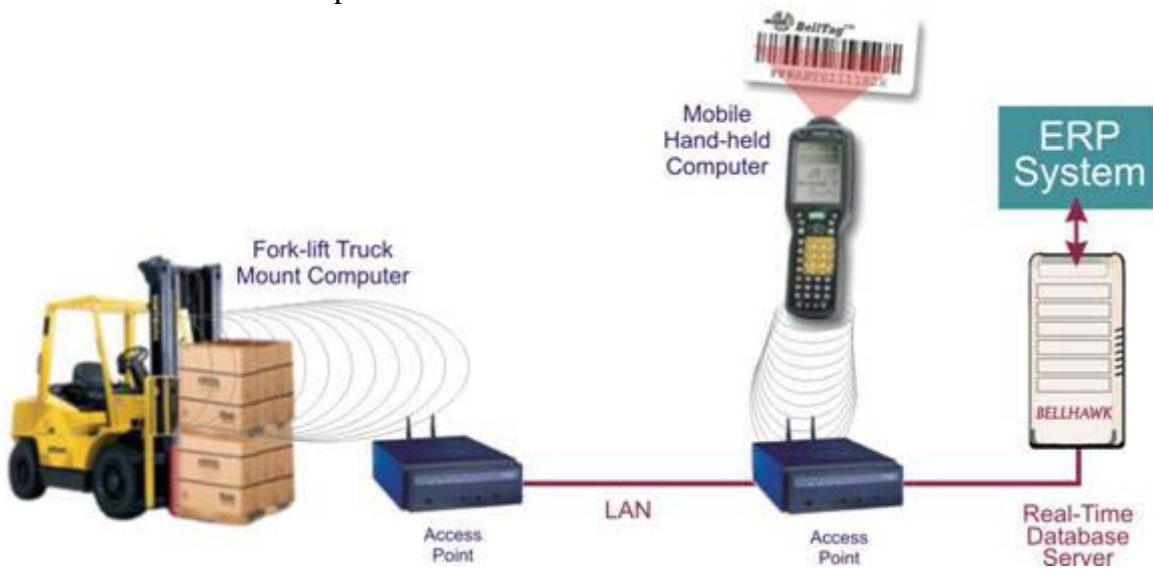
the mobile computing elements act as terminals to the mainframe computer on which typically an ERP system is running. All data entry takes place directly into the ERP system via wireless access points, typically using IEEE 802.11b protocols. The mobile computers typically act as “green screen” terminals and have little or no built-in intelligence.

In a batch operation:



The mobile computers are used to do their data collection independent of the mainframe. They each have a computer program and sufficient downloaded data to be able to perform their transactions completely independently. They typically synchronize their data with a database server whenever they are placed in a cradle. This database server then exchanges data with the ERP system in real time or in periodic batch updates.

In an store-and-forward operation:



the mobile computers are capable of independent operation in batch mode but synchronize their data with the database server whenever they are able to communicate with an wireless access point.

From a software viewpoint, the wireless terminal operation is the simplest to implement but it has a number of disadvantages:

1. The system will not work without total wireless coverage. The 2.4 GHz radio transmission used in an IEEE 802.11b wireless systems requires a direct line of sight between the mobile computer and the access point. The radio waves will not go through anything that conducts or reflects electromagnetic waves. This includes steel racking, concrete walls with rebar, drums of liquid, cases of frozen goods, fork-lift trucks, and people (walking bags of liquid).
2. To achieve total wireless coverage may require 20 to 30 access points or more for a large warehouse at a cost of a thousand or more dollars each. Even then operational blind-spots may occur as material is moved around the warehouse or the warehouse is reconfigured. Note that it is not possible to use inexpensive "office" wireless access points in a warehouse. Access points are placed high up in the warehouse roof to achieve best coverage. The temperatures here can range often from below freezing to well over 120 degrees F. Wide temperature swings will cause condensation that can destroy an "office" access point within a day. For warehouse use, the access points need to be sealed against moisture and dust and may need to have auxiliary heaters if they are to operate below 0 degrees F.
3. The ERP system must be up all the time the warehouse is operating as there is no staging of data. Also any loss in communications usually results in a loss of data.
4. Unsophisticated warehouse personnel have to deal with the complexities of the ERP systems screens. The system cannot be customized, especially with respect to user interaction, without customizing the ERP system. Customization of the ERP system is generally not a good idea as it interferes with the ability to do version upgrades. This precludes presenting a simplified user interface.
5. The system is limited to the data abstractions present within the ERP system. The use of concepts such as "license plate" tracking and nested container tracking, can dramatically simplify material tracking. Most ERP systems cannot handle these concepts.
6. It is very difficult to implement interfaces to weighing scales to automatically record weights without typing in the numbers.
7. Scanning vendor data from multiple 1D barcodes or a single 2D barcode on containers at time of receiving, automatically matching these up with open POs, and entering the data into the ERP system is impossible for most ERP systems without significant customization due to the complexities of most ERP system receiving screens.
8. Most ERP systems have no concepts about material movement restrictions based on quality control approvals. They are not able to handle quarantine and non-conforming material handling with appropriate operator warnings.

These problems can be overcome with a batch system as follows:

1. Material handling transaction data is saved up in the batch unit until it is transferred to the database server. It is saved here until it is relayed to the ERP system. Data cannot be lost due to lack of communication. Data could be lost if the battery goes flat on the mobile computer but usually the data is stored in flash memory where it is retained even if the batteries go flat.
2. No wireless access points are required but battery recharging/data communication cradles are required for each mobile computer. Industrial cradles typically cost about \$200 each and connect either to a PC or directly to the LAN. Data can be collected anywhere including on truck delivery routes, storage yards, and other locations remote from the warehouse and then uploaded when the batch unit is placed in its cradle.
3. The software in the batch mobile computer can be readily customized to make it very user friendly and just capture the necessary data. Also the software can deal with QC related move warnings as the status of each container in the warehouse is stored in each mobile computer. Some batch systems, such as those from BellHawk, can deal with abstractions such as license plate tracking and nested containers. They can also handle FDA signature and data capture requirements.
4. It is possible to automatically capture data from weighing scales using IrDA infra-red interfaces found in many mobile computers.
5. Batch systems can be customized to scan a wide variety of vendor 1D and 2D barcode formats and automatically match the data against the open purchase order data downloaded into the hand-held units. Receipts can be automatically uploaded into the ERP system once items are received.

A disadvantage with a batch system is that the data only gets updated whenever a mobile computer is placed in its cradle. This can cause operational problems when the material is to be moved again before the data in the unit used for the prior move has not yet been synchronized.

If material handlers synchronize their batch mobile computers more often than material is moved there will never be a problem. If they forget, however, the location of material may not be known to other batch mobile computers. Another disadvantage with a batch system is that it cannot be used with fork-truck mount units as these cannot be easily data synchronized by placing them in a cradle.

Fortunately technology has cured one of the big disadvantages of batch units. It used to be that synchronization was a very complex process, with the user being required to plug in the batch unit into a PC by a cable and then start programs running in the PC and in the batch unit itself. Today, with many batch mobile computers, when the unit is dropped into its cradle the data is automatically synchronized with no user intervention. All the user has to do is wait until the "Sync" light goes out, indicating synchronization is complete, and then take the unit out of the cradle.

All the advantages of the batch system can be retained, while overcoming the disadvantages, by using a store-and-forward system. This system works in batch mode but the data is synchronized with the database in the server whenever the wireless unit is within line of sight of an wireless access point. In this case, a limited number of access points are located so that material handlers pass by these frequently. There is no need to achieve full wireless coverage for the system to operate and the batch units can be used at remote locations away from the warehouse without a change in operator interface.

The store-and-forward computer approach can be used with fork-lift truck mount units as well as with handheld mobile computers. Data is now updated frequently without user intervention so that there is not a problem with missing data due to lack of synchronization.

In the case of handheld units, there is no need for the cradles, as batteries can be recharged in a charging rack and replaced as needed without losing the data in the handheld unit. This enables the handheld computers to be used 24x7 with no time lost for synchronization and battery charging in a cradle.

The store-and-forward method can also be used with mobile computers equipped to communicate with the cell-phone network. Here the data is relayed via the cell-phone network to the nearest tower and thence to an internet portal. The data packets are then relayed to the server over an Internet connection. This enables material tracking to take place in remote locations whenever there is cell phone connectivity. The disadvantage is that cell-phone coverage is limited, especially inside many factories, and the data rate is much less than with a IEEE 802.11b wireless connection (9600 baud versus 11 Mbits per second).

## **Conclusion**

The wireless terminal approach is the simplest to implement, except for the placement of the wireless access points, but the most limited in its capability without substantial customization to the ERP system to which it interfaces. The batch approach has a wide range capabilities and is typically the easiest and lowest cost to implement. The store-and-forward approach has a wide range of capabilities, is easy to customize, and its hardware implementation costs are usually significantly less than using a wireless terminal approach.