Emerging economies, social and political transitions, and new ways of doing business are changing the world dramatically. These trends suggest that the competitive environment for manufacturing enterprises in 2020 will be significantly different than it is today. To be successful in this competitive climate, manufacturing enterprises of 2020 will require significantly improved technological capabilities. The acquisition of these capabilities represents the challenge facing manufacturing.

A new competitive environment for industrial products and services is emerging and is forcing a change in the way manufacturing enterprises are managed. Competitive advantages in the new global economy will belong to manufacturing enterprises, which are capable of responding rapidly to the demand for high quality, highly customised products. Operating competitively is becoming more difficult as product variety and options increase, product complexity increases, product life cycles shrink, and profit margins decrease. In addition, the capital costs of manufacturing technologies are extremely high. These factors impose high productivity levels for labour and manufacturing facilities. There is also the need to create the next generation manufacturing systems with higher levels of flexibility, allowing these systems to respond to very dynamic market demands.

Next generation manufacturing systems

The results of a study carried out in the United States for establishing the visionary manufacturing challenges for 2020 (National Research Council, 1997) defined the following six grand challenges for manufacturers that represent gaps between current practices and the vision of manufacturing 2020:

- **Grand Challenge 1**: Achieve concurrency in all operations.
- **Grand Challenge 2**: Integrate human and technical resources to enhance workforce performance and satisfaction.
- **Grand Challenge 3**: “Instantaneously” transform information gathered from a vast array of diverse sources into useful knowledge for making effective decisions.
- **Grand Challenge 4**: Reduce production waste and product environmental impact to “near zero”.
- **Grand Challenge 5**: Reconfigure manufacturing enterprises rapidly in response to changing needs and opportunities.
- **Grand Challenge 6**: Develop innovative manufacturing processes and products with a focus on decreasing dimensional scale.

In addition to these grand challenges, next generation manufacturing systems (NGMS) will be more strongly time-oriented while still focusing on cost and quality. An NGMS will need to satisfy the following fundamental requirements:

- Enterprise integration.
- Distributed organisation
- Heterogeneous environments
- Interoperability
- Open and dynamic structure
- Co-operation
- Integration of humans with software and hardware
- Agility
- Scalability
- Fault tolerance.

All of these requirements have to be satisfied by new technologies that allow a company to integrate all its operations vertically and horizontally to achieve enterprise integration (EI). EI consists of connecting and communicating all the functional areas of an organisation to improve synergy within the enterprise and so achieve its mission and vision in an effective and efficient manner. The integration concept of speedily providing the right information at the right place at the right time under the right format throughout the enterprise is therefore evolving. EI (Vernadat, 2002) covers:

- Efficient business process management, integration and co-ordination
- Team collaboration supported by computer-supported collaborative work (CSCW) for concurrent design and engineering activities
- Increased flexibility throughout the company
- Product life cycle management throughout the existence of a product
- Interoperability of information technology solutions, systems and people to face environment variability in a cost-effective way.

Among all these issues, process management, integration and co-ordination remains the most challenging one because of its knowledge-intensive nature (including problems dealing with semantic unification), and the need for sound negotiation mechanisms among executing agents.
Recent advances in information and communication technologies have allowed manufacturing enterprises to move from highly data-driven environments to a more co-operative information/knowledge-driven environment. Enterprise knowledge-sharing (know-how), common best practices use, and open source/web-based applications are enabling the achievement of the concept of integrated enterprise and hence the implementation of networked enterprises.

Wireless technology: state-of-the-art

Wireless technology was developed in the 1920s when it was used as a method to send telegrams, later for radio (also known as walkie-talkie), and to develop digital communications offered today. Recently the use of wireless technology has seen a fast growth, due to the increase of requirements (Morel, et al., 2003) of telecommunications, data transfer and IT devices in companies, education and homes. These requirements are mentioned by Novel Networks:

- High communication speed
- Shared access to files, data/knowledge bases
- Exchange of picture, voice – multimedia applications
- On line/real-time access
- Access for anybody, from anywhere, at any time, mobility
- Reliable, secure exchange of information
- Intelligent user interfaces
- Easy and cheap installation.

Although not all of these requirements have been implemented in one type of network, there are networks that fulfill some of these characteristics, depending on the application. Within wireless technology, different platforms exist (Intelligent Manufacturing Systems, 1994; National Research Council, 1997) that are currently in use and their usage is limited depending on the application. A structured overview of the different wireless technologies based on (Mezgár, 2004) is shown in Table 1.

Each one of these platforms differs from the others; each has singular characteristics of transmission and reception, inherent properties of design for fulfilling some specific objective (bandwidth, transmission frequency, transmission distances) and are in common use today.

Application of wireless technology in NGMS

Nowadays, manufacturing enterprises in general have adopted five or four functional levels to realize their function. A de-facto standard has already emerged, by the petition of various standardisation bodies such as ISO and NIST (National Institute of Standards and Technology), together with various European projects within

<table>
<thead>
<tr>
<th>Wireless network type</th>
<th>Operation frequency</th>
<th>Data rate</th>
<th>Operation range</th>
<th>Main characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satellite</td>
<td>2170 – 2200 MHz</td>
<td>Different (9,6 kbps - 2 Mbps)</td>
<td>Satellite coverage</td>
<td>Relative high cost, availability</td>
</tr>
<tr>
<td>WWAN GSM (2 - 2,5 G)</td>
<td>824 - 1880 MHz</td>
<td>9,6 - 384 kbps (EDGE)</td>
<td>Cellular coverage</td>
<td>Reach, quality, low cost</td>
</tr>
<tr>
<td>3G/UMTS</td>
<td>1755 - 2200 MHz</td>
<td>2,4 Mbps</td>
<td>Cellular coverage</td>
<td>Speed, big attachments</td>
</tr>
<tr>
<td>iMode (3G/ FOMA)</td>
<td>800 MHz</td>
<td>64 - 384 kbps (W-CDMA)</td>
<td>Cellular coverage</td>
<td>Always on, easy to use</td>
</tr>
<tr>
<td>WWLAN IEEE 802.11a</td>
<td>5 GHz</td>
<td>5 GHz</td>
<td>30 m</td>
<td>Speed, limited range</td>
</tr>
<tr>
<td>IEEE 802.11b</td>
<td>2,4 GHz</td>
<td>11 Mbps</td>
<td>100 m</td>
<td>Medium data rate</td>
</tr>
<tr>
<td>IEEE 802.11g</td>
<td>2,4 GHz</td>
<td>54 Mbps</td>
<td>100 - 150 m</td>
<td>Speed, flexibility</td>
</tr>
<tr>
<td>Bluetooth</td>
<td>2,4 GHz</td>
<td>720 kbps</td>
<td>10 m</td>
<td>Cost, convenience</td>
</tr>
<tr>
<td>UWB</td>
<td>1,5 – 4 GHz</td>
<td>50 - 100 Mbps</td>
<td>100 - 150 m</td>
<td>Low cost, low power</td>
</tr>
<tr>
<td>ZigBee</td>
<td>2,4 GHz, 915 - 868 Mhz</td>
<td>250 kbps</td>
<td>1 - 75 m</td>
<td>Reliable, low power, cost effective</td>
</tr>
<tr>
<td>Infrared</td>
<td>300 GHz</td>
<td>9,6 kbps-4 Mbps</td>
<td>0,2 - 2 m</td>
<td>Non-interference, low cost</td>
</tr>
</tbody>
</table>

Table 1: Main characteristics of wireless networks.
Concerning wireless sensors networks (WSN)

There is a wide range of applications where the WSN is extensively used, and its development in other applications is growing. There are applications from building automation, to military equipment, chemistry process industry, environmental research, and even surgical procedures. Each application has its requirements (Zhao and Guibas, 2004), which must be accomplished to make it work. Factors to consider are:

• The number of sensor nodes in a sensor network can be several orders of magnitude higher than the nodes in an ad hoc network
• Sensor nodes are densely deployed
• Sensor nodes are prone to failures
• The topology of a sensor network changes very frequently
• Sensor nodes mainly use broadcast communication paradigms whereas most ad hoc networks are based on point-to-point communications.
• Sensor nodes are limited in power, computational capacities, and memory.

Sensor nodes may not have global identification (ID) because of high overheads and the large number of sensors.

Sensor networks may consist of many different types of sensors such as seismic, low sampling rate magnetic, thermal, visual, infrared, acoustic and radar, which are able to monitor a wide variety of ambient conditions that include the following:

• Temperature
• Humidity
• Vehicular movement
• Lightning condition
• Pressure
• Noise levels
• Proximity
• Mechanical stress levels on attached objects
• The current characteristics such as speed, direction, and size of an object.

The sensor nodes can be used to sense continuously, for detection of events, identification of events, location, and local control of actuators.

The WSN can be used as a wired sensor network, (Fig. 1), with the following advantages:

• Mobility
• Fast reconfiguration.

Factories are changing the wired sensor for the networked sensor, eg. the use of different technologies (profiBus, profinet, CAN, ASi, etc.).

An individual machine has sensors for verifying initial conditions and security procedures. In the manufacturing process WSN can sense light, temperature, sound, acceleration, etc. Without wiring the sensor, this technology can give mobility, achieve fast device mounting, interchanging and redundant/non-redundant feedback of variables. (Fig. 2).

Inspection and traceability

WSN can track a product in the process or in the workshop and must be able to make inspections and corrections of the product information to feedback to a control computer, so that an informed decision can be made on the products progress (Fig. 3). This system can give information on the location of the part, process failures, quality process, so eliminating the need for manual pallets scanning.

Controls (PLCs, CNCs)

WN can be used in multiple wireless cells joined by a wireless local area network (WLAN) and the PLC slave can communicate with the PLC.

With a wireless tablet PC, we can take control of the machine (HMI), and this system eliminates the big HMI. Fig. 4 (a), (b) (see next page).

Shop floor management and manufacturing execution systems

WSN can track products in the process while the network captures the product name or number. It starts with processing the information of the product such as a part name, special treatments, and instructions on the product, i.e., the product genealogy. The process is then modified according to this information. It may change feed speeds, position, velocities of manipulators, etc. The different cells can interchange information for manufacturing the correct part or element. WN is useful for communicating to the shop floor and the lower levels (industrial network) with the wireless office network (WON) for total integration and monitoring of the facilities.

The WN link provides all the required information of the warehouse and the raw materials and supplies. There can also be a WS counting how many products are in stock and how many have been delivered. All this information is helpful to know the overall production managed by the industrial network, and also the info of the WON on client requirements to be able to optimise the production. Also for drafting and designing better models for production, optimising or implementing marketing plans and to evaluate maintenance costing once a specific number of products have being produced.

Interoperability of ERPs, MES and PLCs

The main problem with ERP or MES is "bad information". WN can send information automatically to an ERP database without human intervention. With mobiles PCs (laptops), or handhelds, personnel can get information about the status of machines, critical alarms, and check the work in process (WIP), verify operations instantly, track sales etc. This system can assist in Kanban/Just-In-Time strategies.

Interoperability of supply chain systems

(Warehouse management)

WN can manage the inventories in the warehouse; give information about purchased raw material, selling of goods, etc. using a PDA.
Concerning wireless personal area network (WPAN)

Wireless LANs connected to automated handheld computers on manufacturing or factory floors are a viable alternative to wired LANs. Laying cable in these environments has proved to be cost-prohibitive, or not feasible because of the size of the warehouse. Also changes in assembly lines are frequent and many employees do not work in the same fixed location for a fixed time. In this study, we have seen that workers and management in the manufacturing environment need instantaneous access to accurate information so they can improve track orders, production runs, and production quantities in real time.

Wireless LANs aid production, maintenance, and troubleshooting (repair) processes at production bays of a foundry, production lines of an automotive manufacturer, and the outside work area of an aircraft manufacturer. The use of production planning and control software combined with wireless LAN technology illustrates the positive effect of this specific IT on an organisation. A typical medium-sized to large manufacturing firm must stock, control and ensure the availability of thousands of items (end products, parts, and raw material). Further, production of the parts and raw material must be co-ordinated to ensure that the firm meets order commitments and production plans. Using manufacturing software with automated inventory status reporting, order processing, production scheduling, and invoicing features, made it possible for companies to control system complexity. But in this study, we found that having a wireless LAN connected to this software enabled operators to go beyond second-guessing the age of the information coming over the wire. It appeared in real-time or nearly real-time. This combination of hardware and software reduced the control and co-ordination and associated costs.

Potential pitfalls of the applications

The main reasons could be:

- The cost involved
- Complexity of technology
- Reliability of technology
- Limited end-user applications
- Lack of technical expertise
- Project size and duration
- Management support.

Nevertheless, the enthusiasm of the technologists and research community remains intact and the future looks bright for the potential application of wireless technology in manufacturing.

Conclusions

Wireless technology is still developing and currently mostly relies on advanced computer networks, the worldwide web and the internet, platforms integration as well as data exchange formats. However, system interoperability is still inadequately addressed compared to real needs.

A big problem is that wireless technology is almost totally ignored by small and medium enterprises (SMEs) and there is still a long way to go before SMEs will master this technology. It is the author’s opinion that these technologies would better penetrate and serve any kind of enterprises if:

- There was a standard vision on what wireless technology really is and if there was an international consensus on the underlying concepts for the benefit of business users.
- There were de facto standards that will make companies feel secure on their investments.
- There were real commercial applications available, taking into account the needs of industry.

- There were design patterns of components available as (commercial) building blocks to design, build, and implement large-scale systems.
- There were commercially available integration platforms and integrating infrastructures (in the form of packages of computer services) for plug-and-play solutions.

These are some of the challenges to be urgently solved in the coming years to build more wireless applications in manufacturing.

References


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