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# Modern Building Services - More Than Computerized HVAC

by A.D. McKinley

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Résumé

L'auteur examine ici la question de la modernisation des équipements du bâtiment : CVC, éclairage, sécurité incendie, sécurité, moyens de déplacement et distribution de l'électricité. Il traite aussi des exigences croissantes des locataires au niveau de la bureautique et des télécommunications.

En examinant l'état actuel de la technique, l'auteur clarifie la définition de ce qu'on appelle souvent «les immeubles intelligents», qui utilisent pour leurs équipements les technologies du calcul, de la commande et des transmissions numériques, et où les équipements des locataires sont complétés par un service de transmissions numériques. Il fait observer qu'il ne convient peut-être pas de définir des exigences technologiques minimales visant la désignation d'un immeuble comme «intelligent», car les caractéristiques d'un bâtiment, comme celles de n'importe quel produit, doivent correspondre aux besoins du client. Il se peut toutefois, comme il est expliqué dans l'exposé, que ces besoins ne soient pas bien définis ni compris.

L'auteur décrit brièvement le système de location multiple d'équipements et ses rapports avec les équipements modernes du bâtiment. Il étudie les problèmes qui se sont posés à ce niveau et les systèmes qui pourraient voir le jour, notamment un nouveau type d'équipement du bâtiment dit «de transmissions». Il présente une liste de questions de recherche-développement. Une évolution semblable se produit dans le domaine des bâtiments d'habitation, mais l'auteur se limite aux grands immeubles commerciaux.

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# MODERN BUILDING SERVICES— MORE THAN COMPUTERIZED HVAC

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ABSTRACT

This paper reviews modern building service practices within the traditional building services of HVAC, lighting, fire safety, security, people movers, and electrical power. It also examines the increasing communications requirements of the tenant services of office automation and telecommunications.

By examining the state of the art, the paper clarifies the definition of what is often referred to as "smart buildings" as being the use of digital computer, control, and communications technologies in building services and the provision of digital communications to support tenant services. It also cautions that it may be inappropriate to define minimum technological requirements for labeling a building "smart", since the options within a building space, like any product, should address the needs of the customer. As is discussed, however, these needs may not be well defined nor understood.

Shared tenant services and their relationship to modern building services are described briefly. Problems that have arisen with the current systems and possible future developments, including a new building service called communications, are discussed. A list of research and development questions is presented. Although similar developments are underway in residential buildings, discussion is limited to large commercial buildings.

## INTRODUCTION

Modern building services, which include heating, ventilating and air conditioning, lighting, fire safety, security, people movers, and electrical power distribution have all made use of modern digital computer and communications technologies. This has prompted the use of the adjective "smart" when referring to some of the large buildings that have installed a significant portion of these new systems. This term has not been readily accepted for a number of reasons: one is that it is seen as a normal evolution of the use of technology in buildings, but the number and cost of the systems being sold are significant.

According to one study, revenues for smart building related products and services were $5.18 billion (U.S.) in 1985 and are expected to be $13.51 (U.S.) and $45.96 billion (U.S.) in 1990 and 1995, respectively (International Resource Development Inc. 1985).

Another influence on the development of these building service systems is the large increase in the automated tenant services of office automation and communications. This is causing an increase in occupants' demands for power and for communications wiring in the buildings.

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Some definitions of smart buildings include shared tenant services (e.g., office automation equipment), which are provided by a building owner and therefore could be considered a building service.

Although a great deal of progress has been made in the development of building services, research and development is needed to advance them further.

## MODERN BUILDING SERVICES VS THE SMART BUILDING

The adjective "smart", with reference to building services, began to appear in 1984 as a result of the use of digital electronics by service manufacturers and building owners to improve building service control systems and by the building occupants to meet their office and telecommunications needs. The evolution from the old electrical/mechanical/manual building services to digitally controlled systems was thought by some to be significant enough to be called smart, although "automated" might be a more appropriate adjective. The systems being installed make use of modern computer modeling and control techniques and digital communications technologies but do not yet attempt to implement true adaptive reasoning nor artificial intelligence.

Another reason that agreement on a definition has been difficult is the fragmented nature of the building industry. Each building and tenant service is supplied by a different group of manufacturers and retailers who have their own definition centered on their area of interest. The building service industry defines it as automated building services supported by communications, the telecommunications and office automation industries define it as digital communications for telecommunications and office automation and the shared tenant service providers focus on their tenant support packages to the exclusion of building services.

An examination of the services that are actually being installed shows that the definition of smart building services is;

> "The use of digital computer, control, and communications technologies in building services and the provision of digital communications to support tenant services."

This definition is based on the building services that are built into the building such as heating, ventilating and air conditioning (HVAC), lighting, fire safety systems, security, and people movers such as elevators and automated doors. It also includes communications and power support for tenant services such as office automation (word processing, publishing, dictation, management information systems etc.) and communications facilities (telephone, telex, facsimile etc.) but does not include the implementation of these services.

Shared tenant services (STS) refers to the provision, by either the owner or a single firm, of tenant services in a multi-tenant building in which smaller tenants might rent an office automation or communications service rather than buying the equipment outright. These services are often considered, by their providers, to broaden the scope of smart building services beyond the components originally installed in the building.

The foregoing has described the scope of modern building services but has avoided defining what the minimum requirements are before a building can be considered "smart." A building should address the needs of the tenants and only provide those services required to meet those needs since to go beyond that would not provide the building owner with a return on his investment nor would it benefit the tenant. A smart building, therefore, is one that meets the needs of the occupants at an acceptable cost to both the owner and tenant, not one that contains a specified set of these modern services.

When determining the occupant needs, consider that some analysts estimate the life of a large commercial building to be about fifty years and also that they are rarely used in the same way over their lifetime as occupants and their needs change. Conversely, the life of digital electronics is currently about three to five years. This implies that, when the services are installed initially, it would be "smart" to consider the need for adaptability and flexibility to reduce the cost of retrofit.

These changes in building operating techniques are having the same impact as

electronics has had in other common products such as watches, calculators, cash registers, cars, aircraft and every household appliance. As one author concluded (Vincent and Peacock 1985);

> The industries closely aligned to building services are also likely to undergo a major technological change....change is most probable, but as a speedy evolution in building-services technology rather than revolution.

Although these services are being installed now and some of the benefits realized, problems remain such as inadequate sensors, a lack of technology and performance standards, insufficient knowledge about tenant needs and about the true benefits and reliability of the equipment, a lack of coordination due to the fragmented nature of the building industry, and a reluctance, for legal and financial reasons, by designers and builders to innovate. Also, there is little sharing of information or of communications equipment between separate services. This causes duplication of equipment, hinders functional integration between the services, and fills buildings with complex masses of copper wire.

## MODERN BUILDING SERVICES

There are two categories of services in large office buildings: building and tenant. The former are supplied by the building owner for use by all building occupants and are usually included in the rent (HVAC, lights, elevators, etc.), while the latter are brought in by the tenants for their own individual use (office automation equipment, copiers, projectors, etc.). Communications have traditionally been a tenant service; however, the need for communications support has become so universal that it may make more sense for the building owner to provide it.

Some of the general benefits to building owners are a possible increased marketability if tenants are attracted to these facilities, important at a time when the average office space vacancy rate is about 17.6% throughout North America (Building Owners and Managers Association 1986), and greater flexibility in adapting their buildings to different tenants needs (estimates are that 25% of office electrical equipment moves each year [Norris 1986]). There may also be direct financial gains through the sale of tenant services and reduced installation and operating costs as a result of the use of inexpensive electronic equipment, better energy control, and cheaper maintenance. The cost of installation is about $3.50 CDN per square foot, although this depends upon the options selected, increasing as functionality is added (Sendell 1987). Tenants benefit from one stop shopping for a number of services, from access to otherwise costly office and telecommunications services, from safer and better environmental conditions, and from improved and cheaper communications.

### Building Services

About $1.8 billion (U.S.) was spent on building automation systems in the United States in 1985 and an estimated $2.5 billion (U.S.), $5.1 billion, and $12.7 billion (U.S.) will be spent in 1987, 1990, and 1995 respectively (International Resource Development Inc. 1985).

Building services are created when it becomes more cost effective to supply a service cooperatively via the building owner than individually by each tenant. Of all the services, HVAC and lighting systems are by far the most energy intensive, so control systems that conserve energy while providing satisfactory performance are a major consideration, although by no means the only ones. The services currently being installed in most large office buildings are;

- HVAC: provide thermal comfort, humidity control and adequate ventilation.
- Lighting systems: provide overall illumination for all tenants and lights in common areas.
- Fire safety systems: for smoke and fire detection and control.
- Security systems: to control access and detect unauthorized entry.

- People movers: elevators, escalators, walkways, and automatic doors.

- Electrical power: supply and distribution of electrical energy.

The majority of new systems use a hierarchical, distributed microprocessor structure, similar to that shown in Figure 1, to monitor and control the equipment, although the number of levels and the hardware vary between manufacturers and the type of service.

At the bottom level, sensors, detectors, and transducers are homewired (directly wired) to field processing units (FPUs), which convert sensor signals from analogue to digital (although many new sensors are digital), control any equipment actuators or relays, and communicate with the central processing unit (CPU) for the application. The FPU may have local intelligence to perform control strategies that can be locally programmed or downloaded from the central processing unit

FPUs are usually networked to an application specific (HVAC, lighting, security, etc.) supervisory computer that may contain some form of error detection and exception handling, scheduling, energy management and reporting software.

The multi-layer approach simplifies each microprocessor's programming and allows for both redundancy of equipment and possibly re-allocation of duties automatically should one piece of equipment fail. If the FPU loses communications with the central processor, it usually has a fail-safe mode that would allow it either to continue to operate as per the last instructions or to reset to some default mode. One application computer may also monitor and control more than one building.

A few installations further connect these application specific CPUs to an overall building service computer; however, this tends to be a management information system rather than a controller. Inter service systems usually exist only where one manufacturer is involved in more than one service. The lack of standards and the fragmented industry discourage logical integration at this level.

Automatic component testing and diagnostic procedures in case of failure increase the overall reliability of these systems, since errors such as a faulty smoke detector are identified immediately rather than on the next maintenance cycle (each sensor can be checked automatically as frequently as every few seconds). This also reduces the cost of maintenance, first by reducing the labor required to test all of a system's components and, second by allowing preventive maintenance to be done less frequently, as it can also be based upon actual usage time for equipment rather than the previously used elapsed time. For example, preventive maintenance servicing of a fan may be based upon the fan's run time rather than being performed every three months regardless of usage.

Some installations have eliminated the 24-hour onsite operator by having the computer log minor problems and report major ones to the security guard for the complex or by having it phone the operator at home automatically and then allowing him to make adjustments from there.

## Heating Ventilating and Air Conditioning (HVAC).

The digital computer based control strategies used frequently include scheduled setback during unoccupied hours with local or building overrides, optimum start/stop for large equipment, and synchronized duty cycling and demand monitoring for load levelling and shedding. Overrides for the HVAC system are often inserted manually by the operator who must be informed in advance of off-hours usage, rather than dynamically at the time required. The control strategies may make use of thermal storage techniques for redistribution of hot or cold air at a later time.

Most large HVAC systems installed today use direct digital control (DDC) in the bottom level control loop (see Figure 1), although some pneumatic systems are still being installed. In addition to handling the input and output requirements of the communications system, the local DDC computer (or FPU) will contain the energy management control software for the equipment connected to it. The DDC controllers are then networked back to a central processor (often a common personal computer or similarly sized processor) for overall control and monitoring including report generation, data plotting, alarm reporting and maintenance coordination. This central application processor is usually able to download the required

programs to the DDC controllers when needed. Some installations are moving toward complete decentralization to the extent that the central application processor is omitted completely; however, the controllers are still networked and an operator information station can be added anywhere in the network.

## Lighting Systems

Lights may consume as much as 50% of the average building's operating energy (Crisp 1984) and, in turn, produce high thermal loads on the air-conditioning systems. New technologies such as smaller diameter tubes, new film reflectors, and more active trichromatic phosphors have increased the efficiency of fluorescent lamps and their ballasts and of incandescent lamps significantly, but energy control systems are still important. The development of solid state ballasts also allows full and remote dimming capability for fluorescent bulbs.

There are three basic approaches to automated lighting control: programmable, dimming, and occupancy sensors, which can present savings of between 30% and 50% of the energy used for lights (Joers 1986).

The most common programmable lighting control technique is the scheduled on/off, which usually schedules all lights off automatically one hour after normal working hours (flickering warns occupants five minutes before the shutoff) and in some cases at lunch and at breaks. Local overrides using the light switches or by dialing a code on the telephone permit after hours use by tenants, cleaning, and security staff. Lighting schedules are usually changed by phoning the building operator, who then modifies the parameters on his computer. The tenant does not usually have direct access to the system.

Since light level needs depend upon the way the area is being used, dimming can be useful to the tenant as a feature as well as an energy saving method of reducing light energy depending on the daylighting in the area. A common installation is an inexpensive dimming system in which the center lamp of a three lamp fluorescent fixture is wired separately from the other two. This allows the control system three levels of light output by simple switching. Studies have shown, however, that people may accept a gradual dimming but object strenuously to lights being switched off automatically as daylight increases (Boyce 1984). The full range dimming of fluorescent lights is possible, although the cost of the ballast is still high.

Occupancy sensors, the most common of which are infrared, ultrasonic, and microwave, are used in programmable and dimming systems to prevent the lights from coming on if the room is unoccupied and to replace a manual light switch in infrequently occupied areas such as storage rooms. They are also used in single-occupant offices, where tests have shown that this type of office is only occupied an average of 4 hours per day (Joers 1986). Cost calculations show that fluorescent lights should be turned off if the room is vacant for as little as five minutes and incandescents for an even shorter period (Carrière and Rea 1986).

As one study concluded about the potential for lighting control systems to reduce energy consumption (Crisp 1984);

> There is little doubt that very significant savings can be achieved. Major contributions result from eliminating lighting use when occupants are absent (time switching / scheduling and occupancy linking) and from ensuring that daylight is better utilized (localised switching and daylight linked switching/dimming).

The study also adds that;

> The provision of convenient local controls for occupants as part of an overall control system can be both energy efficient and, perhaps equally important, has the potential to improve user satisfaction.

Beyond the question of saving energy through the use of control systems is the need for a better understanding of the effect of poor lighting on user performance and satisfaction. Keeping in mind again the high cost of salaries compared to the capital and energy cost of lighting, it is important to understand the effects of a particular control strategy. For example, the energy cost of lighting for one year is approximately equal to one hour of

the occupant's wages. Also, on average, the amount of light that passes through the human eye decreases by age 60 to about one third of that at age 20, which has a direct bearing upon the individual's vision and, presumably, performance (Wright and Rea 1984). Studies have shown that people compensate for low light levels by moving closer to their work (Rea, Ouellette and Kennedy 1985), which may result in eye strain or back problems. As one researcher summed up (Rea 1984);

> More complex and more important than an understanding of the costs associated with the operation of lighting and other systems in a building, is an understanding of how the modulation of lighting affects the occupant. Controls should not compromise the primary objectives of lighting the space, which are to meet the needs of the occupant.

People are particularly sensitive to problems with lighting and are easily frustrated by systems that don't work properly. Systems that turn lights off right at quitting time seem to prompt some people, who previously stayed on, to go home. A general guide would be to use aggressive approaches to lighting control in empty spaces and conservative ones in occupied spaces.

If the telephone code system is used for overriding schedules, an office prankster may cause problems by turning other workers' lights off and on.

Unfortunately, the sensors used to determine the level of daylighting and to detect the presence of people are not always reliable and do not necessarily reflect the occupant's idea of the preferred light level. One building manager reported that the ultrasonic sensors installed in his building were a problem as they were too sensitive and needed to be readjusted from person to person. At times the lights would turn off if the person was not active enough.

Following are some of the technological advances needed in lighting (Verder and Rubinstein 1984): reduced equipment costs, improved equipment reliability, development of scanning photocells, development of scanning personnel sensors, installation of a transceiver in each electronic ballast, development of power-line carrier communications systems.

Computer-controlled lighting systems use a twisted-pair network to connect the lighting CPU to the transceiver panels (FPUs) that are scattered about the building. These panels terminate the 110 volt lines from each fixture and all of the switches and sensors.

## Fire Safety

Once an alarm condition is sensed, the fire safety system sounds some form of local alarm. It may cause all of the elevators to home to a predetermined floor and shut down, call the fire department automatically, initiate smoke control measures that simply shut down all ventilation systems or that pressurize stairwells and the floors around the fire floor while drawing air out of the fire location, and it may automatically close all fire doors.

Developments in the fire detection and control industries have been slightly slower since they involve life safety; however, computers and microprocessors are becoming common. The fire communications network links all smoke and heat sensors, manual pull stations, and sprinkler flow valve sensors, over twisted pair wiring to a central computer that is able to test all of the components constantly for failure. The National Fire Code regulates the type and location of wires and any overrides necessary such as the fire fighting panel.

Despite all of the sophisticated control software, typically fire fighters deactivate the computer system upon arrival, which negates any special smoke control, fire fighting, or evacuation systems. There are several reasons for this, such as a lack of knowledge about how each computer system works, which is compounded by a lack of a standard user interface and a lack of standardized computer software. Older, hardwired, electrical/mechanical fire systems are rigidly controlled so they can be depended upon to work in a crisis. There is some concern about the dependability of the computer hardware and software considering the consequences of a program bug or hardware failure and the hostile environment in which a fire control system must work.

Smoke and fire sensors can produce false alarms, so in many large complexes, the computer does not automatically sound the alarm but sends a level one alert to the security

guard for investigation. The alert will escalate automatically to a full alarm if it is not overridden within a certain period of time.

## Security

More than 300 business premises were broken into daily in Canada in 1984 at which time $175 million dollars was being spent on security equipment (Gobeil 1984). Individual electronic security systems range from $3,000 to $5 million, depending upon the installation, while a 24 hour manned guard post costs between $60,000 and $100,000 per year.

The two components of security are access control and intrusion detection.

The access control sensor may be a security card using a simple magnetic strip or an embedded wire (Weigand effect), a proximity card reader that uses a small electromagnetic field to energize the card, an occupancy sensor such as those used in lighting, or voice (biometric), finger, hand, or retina readers. The last four remain very expensive and are only used in special installations. In most cases, the access is logged and often a check against a permitted access list is made before the security field microprocessor activates the electric door lock, the garage access gate, or the elevator floor buttons. Access may be limited to certain hours of the day or restricted to a part of the building and is controlled via a door or the individual floors on an elevator.

Other sensors, such as motion or heat detectors, pressure sensors, door switches, and vibration sensors, are used to detect unauthorized entry. If a security breach has occurred, all of the lights in the area are often turned on automatically as well as notification of any on site security personnel, possible off-site alarm, and the activation of recording and logging devices.

Access sensors and actuators are connected to field processors, which are in turn connected to the security computer, again over twisted pair wiring. More than one building may be monitored by a single security computer and guard using telephone lines to access building specific security microprocessors. Besides these digital computer networks, closed circuit television is often used, which requires a communications medium such as coaxial cable or fiber optics to carry the information.

## Elevators, Escalators, Moving Walkways and Automatic Doors

In the larger buildings with banks of elevators, complex control computers are used for transportation scheduling to optimize service, prevent crowding, save energy, and provide efficient coverage for the building. The control software tries to anticipate demand based upon the calls received and on high probability floors. Calls from contiguous floors are given to one elevator or priority may be given to coincident calls where one person is getting off and another on at the same floor. It also allows the system to anticipate traffic patterns such as the morning up-peak and evening down-peak and to park cars at strategic locations when not needed.

Revolving doors are often sensor and microcomputer controlled for user convenience, for safety or security. These can also provide hands-free operation for the disabled, although automatic revolving doors can be dangerous for disabled people who may not be able to keep up. Revolving doors with ultrasonic or microwave sensors are used in security areas such as airports to provide one-way traffic (they reverse slowly to push someone going the wrong way back out). Energy conservation measures and modern equipment such as direct coupled DC motors with solid-state rectifiers are used to reduce the operational costs of elevators, escalators, and revolving doors.

In large installations, each elevator cab has a microprocessor that communicates with a bank controller in the mechanical room. The sensors on the cab are homewired, again with twisted pair, to the cab controller, which is homewired to the bank controller.

In addition to the usual floor call and door open sensors, floor identification, velocity, load and position sensors are used.

## Electrical Power

As a result of this computerization of building services, a high priority is often placed on secure, uninterruptable power in case of emergency. Many buildings, therefore, have some form of battery backup, and some critical institutional buildings such as hospitals, penitentiaries and museums have standby generators.

Little has changed in the distribution of electrical power within buildings in the last ten years. Although the power requirements of tenant services are not large, there is usually a shortage of outlets or they are located in the wrong place (many tenants use power bars or extension cords). The technology exists to monitor and control each power outlet and all of the wiring, but such systems are not yet cost effective for large buildings and are only now being developed for residential buildings (e.g., the National Association of Home Builder's Smart House project).

## Tenant Services

Tenant services, in the context of digital electronics, are simply the electronic services that are supplied by the occupants of a building in order to carry out their business. As opposed to building services, tenant services are more user-specific, so the economies of scale realized by having the owner provide these services automatically as part of the rent are not always there. The exception is shared tenant services, discussed later. Automated tenant services can be divided into two groups as follows:

1. Office Automation

   - Word processing, publishing, copying
   - Dictation, optical character readers
   - Electronic filing and file conversion
   - Management information systems
   - Databases and other computer facilities

2. Communications

   - Telephone, telex, facsimile
     Data transfer, access to data bases
   - Electronic and voice messaging
   - Closed circuit television
   - Modem pooling, gateways to external networks

The business of installing tenant service equipment (including permanent support equipment such as PBXs but not including the office automation equipment) in the U.S. was projected to grow from $1.15 billion dollars in 1985 to $1.48 billion in 1990 and to $1.76 billion by 1995 (International Resource Development Inc. 1985).

Many tenant services use some form of communications network, which usually is designed to work with the specific service hardware in use. Often, therefore, more than one network is required to support the various types of equipment. The wires may be installed by the telephone company and/or other service provider and/or by the users themselves and the media may be twisted pair, coax, or fiber optic.

## Shared Tenant Services

Shared tenant services (STS) is the leasing of tenant service equipment to the tenants of a multi-tenant building either directly by the owner or by a single service provider contracted to do so. In a multi-tenant environment, it may make economic sense to share the capital, installation, operating, and maintenance costs of the tenant service equipment among some or all of the tenants and, therefore, in the context of "smart buildings," the provision of shared tenant services can be considered part of smart building services.

Revenues from the sale of these services was expected to jump from $1.58 billion in 1985 to $5.18 billion in 1990 and to $26.7 billion by 1995 (International Resource Development Inc. 1985). There now appears, however, to be a shakeout of the shared tenant service providers, and this market has not grown as rapidly as expected.

## OPPORTUNITIES AND FUTURE DIRECTIONS

### Future of Building Services

Building services are moving toward sharing communications equipment, which does not necessarily mean the functional integration of these services, as each could still remain proprietary and receive only those messages that were addressed to it. Functional integration of the services such that information is passed between them implies a higher level of compatibility than just common communications. This level occurs now with some manufacturers who have products in more than one building service, but an open non-proprietary system will not occur soon. For either hardware or functional integration to be implemented as an open system, a standard will first need to be developed, and, as described later, such work is now underway.

The development of similar control equipment and strategies within each building service has allowed companies who used to specialize in only one service industry to expand into others. As a result, the previously fragmented building service industry may become more unified as some companies expand and others merge. By the same token, standardized non-proprietary communications may allow smaller companies to make components for what are now closed systems and for sensor manufacturers to install more intelligence in their products.

It is now possible for a tenant to control the HVAC for his own work area although the costs are high. Developmental work and mass production coupled with user demand may make this more feasible in the future.

Even though the HVAC system in a building is designed and installed correctly, the building may not operate properly since buildings are often not used as they are designed. The tenant and occupancy type may change completely, walls and partitions may be erected, ducts shut off, unplanned for equipment with heavy thermal loads brought in, or some other similar modification that completely negates the original design. It is not uncommon to find rooms controlled by thermostats or light switches located elsewhere or that no longer have adequate ventilation due to the installation of a partition or even that no longer have the code-required fire sensors. Computers and communications cannot solve these problems directly, however, they are able to signal when design conditions cannot be maintained.

Security systems present the most persuasive argument for a level of integration of all building services in that all of the modern building service equipment could form part of the sensor network. This would mean that a light or a piece of equipment being turned on or an elevator or even a washroom being used could signal an unauthorized entry.

At present there is no sensor system that could signal an escalator to start or stop based upon a person being present. The cost savings of such an operation would need to be balanced against the possible reduction in service life or increase in maintenance costs.

Possible future developments in the fire services might have the computer coordinate an evacuation based upon the location of people in the building in relation to the fire. Dynamic adjustments could be made for traffic congestion or blocked exits. Also, if each building were to contain some form of a data base about itself, then up-to-date building specific information such as fire hazards, emergency equipment under repair, location of toxic substances, and location of disabled people could be available. A mobile fire control computer that could connect to the building fire control computer would allow the fire fighters to make use of this information and of the fire control techniques installed in the building. Exit signs that adapted to the smoke conditions in the room, for example flashing, increasing in intensity, or coupled to an audio alarm, would enhance the likelihood of a person escaping a smoke-filled room.

One possible advantage resulting from the development of power control and distribution systems is increased safety, as outlets could be activated only if a valid appliance were connected, not if a child inserted a screwdriver or if the wires shorted (e.g., Smart House). Also the ability to report power usage by outlet would help to determine where electrical energy is actually being used, and therefore the cost could be billed back to the user and the user would have a better idea of the amount of power being consumed by each device.

## Future Requirements of Tenant and Shared Tenant Services

Electronic tenant services are still being installed at a great rate, which means they will have an even larger impact on building communications and power systems in the future.

Shared tenant service studies profile a reluctance on the part of buyers to subscribe to such services and a resulting shakeout of the suppliers. The results of one such survey of tenants and developers are as follows (Kraemer 1985).

1. Tenant's Response

   - low awareness of potential for shared services.
   - reliability and cost savings were key factors.
   - attraction to basic services such as PBX features, single point of contact, and discounted long distance telephone rates (in the U.S.)
   - most do not require or already have the enhanced services they require.
   - two of three tenants found the shared tenant service concept appealing.

2. Developer's Response

   - STS viewed as a means of attracting tenants.
   - are concerned about reliability.
   - are willing to grant a franchise to an STS provider.
   - see STS as a possible source of income.

Building tenants are accepting STS and computer technology slowly for two reasons. First, senior company managers, who control most of the decision making, are having to adapt their thinking to understand the benefits of computer technology both in the office and in building services. Second, most companies have well-established procedures and have purchased the equipment required to conduct their business reasonably well. No company suddenly needs all of the office automation or the telecommunications equipment or the automated building. Both of these factors are changing as more computer literate managers are promoted and as businesses grow. Typically, computers are used as a means of supporting a growing business with the same level of staff. The change is evolutionary, not revolutionary. Further development of computer networks will reduce the number of different networks required to support all of the tenant services.

## Building Communications - a New Building Service

There can be 10 or more separate communications systems installed in buildings at present and much of the service wiring is homewired. This is not only costly but is extremely difficult to manage. Old wires are rarely removed due to the cost of labor, to a reluctance to reuse old wire, and to the difficulty in determining which wire of a bundle is no longer being used. As a result, buildings are becoming virtual copper mines.

The solution is to develop a building communications network that could be installed cheaply during construction and be used by all of the building and tenant services. In other words, communications could be added to the list of building services. This would not in itself prevent the system from becoming outdated by technological advances, but it would reduce installation and operating costs.

A proper investigation might result in a recommendation for more than one network, such as one for building and one for tenant services or one for low- and another for high-speed communications.

In order for a common building communications system to be developed, either a market standard or a government supervised standard must be developed. At present, a number of government organizations are working on standards that affect all of these communications. The International Standards Organization's (ISO) seven layer reference model for open systems interconnect (OSI) is a basic reference point for other computer communications standards. The Integrated Systems Digital Network standard (ISDN) being developed is intended for world-wide digital communications networks similar to the current analogue telephone network. The Canadian Standards Association (CSA) has empowered a committee called the Technical Committee on Building Facilities Design Guide for Telecommunications to address building wiring standards.

In addition to these government organizations, several large non-service, companies have developed manufacturing and office network standards that also address the problem but have not yet been accepted as de facto standards (e.g., the Manufacturing Automation Protocol (MAP) and the Technical and Office Protocol (TOPs)).

Firms in the service industries are also addressing this issue, but they are doing so by attempting to adapt their existing computer, telecommunications, or building service network proprietary systems rather than researching the needs of all services and producing a properly designed, open system network that all manufacturers could support.

There is much discussion about which medium should be used for this communications network. Twisted-pair wiring is commonly used for telephones and for building services, but some office automation applications and television cables require coaxial or fiber optic cable either for speed or to remove interference. A decision should be based upon a study of requirements.

## Research and Development Required

The technology development cycle is still in the initial phase of technology push where manufacturers are trying to predict the needs of their market for their initial products. The second phase is the refinement of these products by the market as users come to understand how this technology can be used and subsequent phases repeat the first two. This iterative process can be shortened and better results obtained if proper research is conducted into user needs.

The following list shows some of the research needed before these systems develop much further:

1. Develop standard benchmark tests for building service systems that can be referred to in building specifications and performed during commissioning of the building. This would allow building owners and operators to evaluate products and installations properly.

2. Develop machine interface standards such that the same product from different manufacturers would respond to the same control instruction format and all can use the same communications system. This would facilitate integration of services, would allow smaller manufacturers to build products that could fit into a larger system, and would allow the use of a single building communications service.

3. Analyze the future directions of these building services in terms of their incompatibility with the current building codes in order to facilitate the introduction of new systems.

4. Research the need for and advantages and disadvantages of integrating the various services to determine what level of integration would be useful and cost effective.

5. Research the development of expert diagnostic systems for service components and for building operation to simplify building diagnostic and maintenance procedures.

6. Research the extension of the expert systems mentioned above to include artificial intelligence techniques for building operation to develop systems that could be used to operate and commission buildings.

7. Research the effects on human performance of varying environmental and working conditions to determine the cost and human implications of not maintaining certain conditions.

8. Study the level of dependability and durability required of these systems and develop ways of meeting these requirements in order to safeguard occupants in case of failure or to ensure the systems operate properly under hostile conditions such as fire.

9. Research and development are needed to produce equipment that would help to protect people or assist in their egress from a building fire and to better control the electrical and gas usage to prevent accidents.

10. Analyze the above mentioned research and development in terms of the industries involved to identify those who have parallel needs and would be interested in doing some of the work. Where the payback period is too long for private industry or changes for the public good are required, appropriate government facilities should be identified.

## SUMMARY

Modern building services are making increased use of digital computer, control and communications technologies and this fact has prompted some to refer to these buildings as "smart." While this term may not be completely acceptable, there have been some real and useful changes as a result of the application of this technology.

A number of research and development issues need to be addressed if these services are to develop properly and efficiently. These are; the development of standards for testing service equipment and for communications; analyzing the future directions of building services so appropriate code changes can be made; investigating the appropriate level of integration between services; researching the use of expert systems and artificial intelligence for equipment diagnosis and building commissioning and operation; researching the effects of varied environmental and working conditions on human performance; studying the level of dependability and durability required of service systems; researching further ways to protect occupants from accident or fire.

There is a strong indication that a standard building communications system would be beneficial to reduce the costs of installing and maintaining building wiring systems, but further research and development is required to evaluate the possibility, write the specifications, and design the equipment.

There is limited but slowly growing support for shared tenant services, which is the provision of such things as office automation equipment by the building owner.

Computers and communications are being used extensively in building and tenant services now and the future possibilities, with careful planning, are significant and beneficial.

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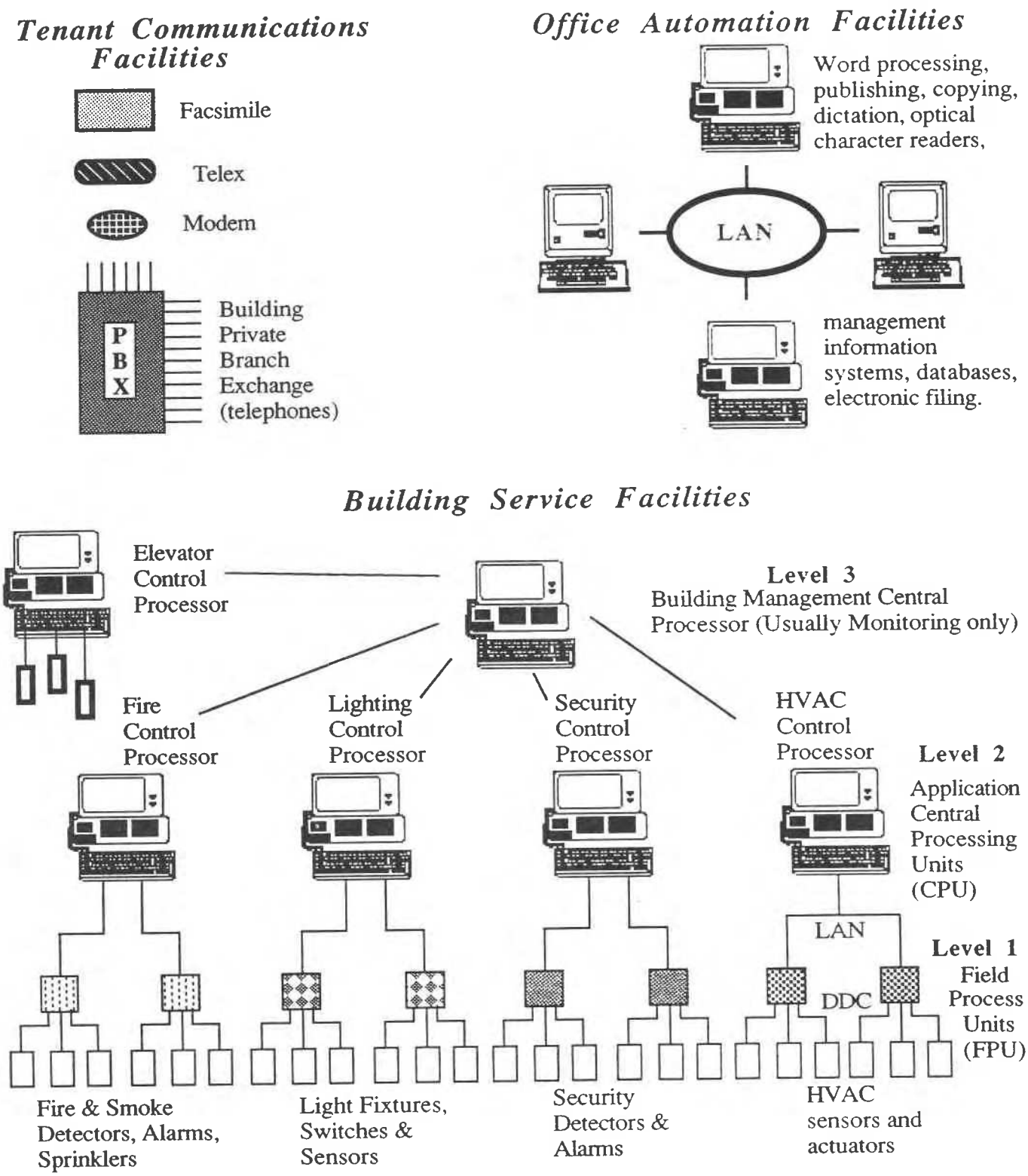


Figure 1 Modern building and tenant service computer systems

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