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# LOCAL AREA NETWORKS - APPLICATIONS TO ENERGY MANAGEMENT

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ABSTRACT

One of the newest advances in computer technology is the Local Area Network. Its many applications in the office environment are well publicized. This paper describes the application of Local Area Networks to another environment: Energy Management systems. The idea of the Local Area Network is described, and it is compared to the distributed processing technique, one that is more commonly used in energy management systems. The two techniques are compared by applying each to common examples, and pros and cons are discussed. Examples of energy management systems using the Local Area Network technique are then presented.

## OVERVIEW

One of the newest innovations in the area of computer technology is the use of Local Area Networks (LAN) in an office automation system. This technique allows separate and independent office workstations and other computers to share information and resources through a common communications link. For example, the central storage of a large computer, or a bank of printers at an I/O station would be available to each of the members of the Local Area Network, if the computer and the I/O station were also on the network. This allows a great amount of flexibility in matters such as central document storage, document handling and printing. Also, the number and types of workstations on the network is very flexible because workstations, or other computers, can be added to the network at any time without greatly affecting the performance of any individual workstation. This is due to the fact that almost all of the resources of a workstation are used strictly within that workstation.

But the LAN can be used for other applications as well. One application of interest is the use of Local Area Networks in a Building Management System (BMS). Such a system could prove to be very flexible in its sharing of data and resources, and in its ability to expand. This paper describes the application of Local Area Networks to Building Management Systems, and it compares these systems to ones using distributed processing and direct digital control, two of the more common system architectures now used in Building Management Systems. Also, examples of system operation using LAN technology (based on the Vanguard I system by Advanced Micro Systems Corporation) are compared with distributed system examples. Finally, some examples of control strategies for the LAN system are discussed.

The comparison of the two architectures begins with descriptions of both the Local Area Network and the Distributed Processing system. A distributed processing system is a group of computers which are subordinate to one central processing computer, commonly referred to as the central unit or "head end". The central unit distributes its workload to the subordinate units. The key idea here is that the central unit, in order to distribute the workload, must direct the operations of all its subordinates. In doing so, it must know all the information that each subordinate unit needs to do its job. This implies that a large amount of memory, or mass storage, as well as a large amount of processing power, are required at the central unit. More simply stated, the size of the "head end" dictates the maximum size of the entire system.

A Local Area Network, on the other hand, is a group of independent computers, within close proximity of each other, that are linked via a common transmission medium to allow information to be exchanged between them. This information exchange allows a network member to share both data and resources with every other member on the network. The key idea in this description is that the members of the network are independent. Resources and information may be shared between the members of the network, but no one network member is dependent on another member, i.e., a "head end" computer, in its operation.

The descriptions of these two architectures show a main philosophical difference in each system's communications. In the distributed processing system, the "head end" actually directs the subordinate units. The relationship between the "head end" and its subordinates is one of a master communicating to its slaves. The master polls its slaves for the current sensor information, and directs the slaves to control their equipment, based on its sensor information and information from other slaves. This type of relationship does not exist on a Local Area Network. Since each unit on a LAN is independent, and no unit directs any operation, the relationship between the LAN units is one of a master communicating to another master. Communications does not occur via polling, but rather it occurs in a direct exchange of information. If one unit needs information from another unit, it will ask the other unit for that information.

A system using the Direct Digital Control (DDC) technique operates in an independent manner, similar to the Local Area Network, but cannot share data and resources with other units. Each DDC unit monitors and controls a small area, for example, an air handling unit. It will monitor temperatures, and control fans. But the DDC unit does not communicate with, or use information from, other DDC units in its operations. When it is part of an integrated system, it will communicate with a "head end" computer (as part of a distributed system), but its communications is limited to informing the "head end" of the status of the equipment being monitored and controlled.

## COMPARISONS BETWEEN LANS AND DISTRIBUTED SYSTEMS

The descriptions of the two techniques reveal five major differences between them. The first difference is the dependence of the computers. In a LAN system, each computer is independent. It does not need to rely on another unit in order to operate. For example, in a BMS controlling a building with four wings, four network units, one for each wing, might be used. Each of the four units would control its wing of the building independently of any other network unit. In a distributed processing system, a central unit must direct the subordinate units in their operations. In our example of the building with four wings, a central unit might direct four subordinate units in the control of the building. In an integrated DDC system, the individual units, although operating independently, must still rely on the "head end" computer to tie all the units together.

The second difference is a consequence of the first. Because of the independence of the units in a LAN, a loss of communications, or a break in the network will not cause a system failure. In the LAN example above, if communications were lost with the unit controlling the west wing, the other three units would continue to operate normally, sharing information and resources. The west wing unit would continue to control its area, but without information from the other units. This may cause some degradation in performance, but for the most part, the wing will be controlled correctly. In general, a communication failure in a LAN system will cause the system to be reconfigured automatically.

A loss of communications in a distributed system, however, can have more disastrous results. For example, if the central unit were to lose communications with the west wing unit , it would be unable to direct changes of control to that unit. (This assumes that the west wing is a DDC unit. If not, the west wing outputs would be frozen in their last state, and the central unit would be unable to change them.) A more serious failure in a distributed system is the failure of the central unit itself. If this were to occur, each wing would operate in a degraded mode at best, or would cease to operate at worst. Without direction from the central unit, the DDC wing units can only continue their current control strategies, while the non-DDC wing units will freeze all outputs to their current state. A change of control strategies, which would normally be dictated by the central unit, could not be implemented independently by the wing units. In general, reconfiguration in a distributed system after a communications failure, must be directed by the "head end".

Another difference, again based on the dependence/independence of the units, is the amount of communications between units during normal operation. In a LAN system, the only communications between units would be shared information, or information needed to share a resource, such as a printer. This communications takes place only when needed. Shared information is data monitored by one unit that is used in control schemes by the other units. The unit monitoring the point whose data is to be shared will send messages to the other units alerting them when the state of the shared data point changes. Some examples of data that would normally be shared are outdoor air temperature and humidity. By sharing this information, sensors for outdoor air temperature and humidity need not be duplicated in the other units. Resource information might consist of information needed to print a report. This information would be sent from the originating unit to the unit controlling the printer. When the destination unit has received the information, the report would then be printed.

On the other hand, in a distributed system, the amount of communications between units during normal operation is much greater than in a LAN system. This is because the current states of all sensors and equipment are continually being forwarded to the central unit by its subordinates, due to the polling nature of the communications protocol, so that the "head end" may record the changes and determine its control strategies. The central unit will then send commands back to the subordinate units directing them in their control of the equipment. This continuous communication polling during normal operation implies that the central unit can become a communications bottleneck during periods of high system activity.

The fourth major difference is the amount of memory needed for the system to operate. In the LAN system, each unit need only have the information to control its own area in its memory. Resources, such as memory and I/O devices can be economically distributed throughout the network. In our example, each wing unit would have the information needed to control just its wing. In the distributed system, the central unit must have the information needed to control all four wings, in order to direct the wing subordinates. This implies that a large amount of memory, mass storage, or both is needed. It also implies that the maximum size of a distributed system is limited by the size of the "head end".

The fifth major difference relates to the ease of expanding the BMS. In a LAN system, another unit can be added by programming its data base, connecting it to the network, and turning it on. It will control its area, and use information from other units when necessary. The ease in the expansion of a LAN system is because a network addition requires no resources from any of the members. Expanding a distributed system, on the other hand, is more difficult because the "head end" unit must be programmed to control another subordinate. The information the new unit needs for its operation must be added to the "head end", and the new unit itself must be connected to the communications trunk. This information in the "head end" which is needed to control the new unit uses some of the "head end" resources, namely memory and disk space. The new unit also places an additional burden on the "head end" as even more communications is now taking place during normal operation. The "head end" is now working harder. In contrast, the LAN system can add any number of units without placing a burden on any system, since each unit operates independently.

## SYSTEM OPERATION USING A LOCAL AREA NETWORK

To illustrate the operation of a Building Management system using the Local Area Network technology, consider the following example. A building's north and east sections, and the parking lot lighting are controlled by Unit One, while the south and west sections, the main entrance, and outdoor building lighting are controlled by Unit Two. The two units communicate via the Local Area Network in order to share outdoor air information monitored in Unit Two, and the electric demand meter information monitored by Unit One. In addition, Unit One also controls a printer.

Normal operation of the system would be similar to the following description. Both units control their respective areas, performing load management, time of day, reset, set point, interlocking, optimization, and other types of control. When Unit Two detects a change in outdoor air temperature, it stores the new temperature in its memory, and also sends a message to Unit One letting it know the new value of outdoor air temperature. This allows Unit One to perform its control strategies that are based on outdoor air temperature even though it does not have an outdoor air temperature sensor. In addition, if Unit One determines that it needs the outdoor air temperature immediately, it will send a message to Unit Two requesting the information. Unit Two will respond by sending the data to Unit One. As this example shows, the transfer of data from one unit to another can be initiated by either unit, by Unit Two when it detects a change in the data, or by Unit One when it needs the data.

Another example of system operation is demand control via the Local Area Network. Unit One detects that the demand value has exceeded the shed point value. It will begin to shed loads at the lowest priority. It will also send a message to Unit Two instructing it to shed a certain amount from the same priority. Unit Two will actually choose which loads to shed. In this manner, the control of loads is performed by each unit separately, while the determination of the amount to be shed is performed by the unit reading the meter. The only interaction is the message from Unit One to Unit Two requesting that some load shedding occur at the specific priority.

One last example of system operation via the LAN is the generation of a report to be sent to a shared printer. Assume that Unit Two generates the report. It will first store the report information in its memory. Then it will send a message to Unit One requesting the printer. When the request is granted, Unit Two will send the report information to Unit One, where it will again be stored in memory. When Unit Two is finished transferring the report information, it will send a message releasing the printer. When Unit One receives the printer release message, the report will be printed.

## LARGER SYSTEMS USING LOCAL AREA NETWORKS

The previous example of a building being controlled by two units in a LAN can be expanded to a number of units controlling a number of buildings. One example of this type of larger system would be a college campus.

The campus Building Management System will need to be more than just an Energy Management system, although the EMS portion of the system will be the larger part. A Security/Access Control system will be needed for security purposes. A fire control/lifesafety system will also be needed. The Local Area Network offers two configuration options: 1) the three sub-systems can be integrated into one facilities management system, or 2) the three sub-systems can operate independently of each other, while still sharing the common communications link. This gives the building manager the option of an entirely integrated system, or a collection of independent sub-systems. In addition, a console unit (or units) can then be added to the system network to provide a central location for monitoring and/or programming the entire system, regardless of the system configuration. In this manner, the LAN allows the existence of a central unit as a monitoring station without the disadvantages of a large "head end" computer found in a distributed processing system.

The campus EMS might be made up of one unit in each larger building, or one unit for two or three smaller buildings. These units will work in the same manner as described in the previous example. The campus access control system will control access to secured areas, as well as perform other security related activities. The fire/lifesafety system will monitor fire alarms, smoke and heat detectors, and other equipment in performing its functions. ( During fire conditions, the fire control unit can also direct the EMS units to control their supply and exhaust fans to contain the fire, rather than feed it, and to purge the smoke, if the sub-systems are integrated.) The monitoring unit will be able to communicate with each and every unit on the LAN. It would be the station to receive all reports, alarm messages, etc. from all the units on the LAN. In this way, the status of the entire integrated system can be monitored or programmed from a central location, as in a distributed processing system.

## REMOTE SYSTEMS AND A MONITORING UNIT

Another application of the Local Area Network technology contradicts the term "Local". The LAN system can be used for central monitoring of a number of remote independent systems. The individual systems are completely independent, and do not share data or resources with each other. However they do share resources with the central monitoring unit by sending reports and other important information to it. This can be done over dial-up phone lines. The unit requesting or sending the information will phone the other unit, and the communications will begin. When the information exchange is complete, the phone connection will be terminated. An example of this type of application would be a chain of retail stores or restaurants, each building having its own independent BMS. The entire chain of systems is then monitored by the regional or national office. In general, any company with multiple buildings, regardless of their locations, could use this application to perform central monitoring of its group of systems.

## SIMILAR EXAMPLES OF SYSTEMS USING DISTRIBUTED PROCESSING

The three examples of Building Management Systems using Local Area Networks that were discussed above can also be implemented using distributed processing. But upon inspecting these implementations, a number of problems that are associated with distributed processing come to light.

Consider the first example of the two units controlling a building and its parking lot. If the system were configured using distributed processing, a third unit would be needed to act as the "head end" for the two subordinate units. The "head end" would need to know all the data that each wing unit would need to operate. This requirement dictates that the "head end" have a large amount of memory and processing power (implying a higher cost). In addition, the reliability problems of distributed systems (discussed above) now come to light. If the "head end" were to fail, the entire system would operate in a severly degraded mode (if the system were a DDC system), or would fail completely, because the subordinate units could not be directed.

In the example of the integrated college campus system, the "head end" unit would have to be immense in its computing power and memory. In addition, to store this volume of information, a large amount of disk storage would be needed, again, adding to the cost. But the addition of a disk adds another source of potential failure to the distributed system technique. A failure in the disk unit can cause the entire system to fail. This possibility, along with the memory and computing power disadvantages, create a number of problems that can cause total system failure, and add to the already existing reliability problems.

If the college campus system was not integrated, the three systems could not be accessed from a central console. This is because the three systems would be completely separate. In addition to the lack of a central monitoring station, each separate unit would suffer from the same faults as any other distributed system.

In the final example of the remote units in a group of stores or resturants reporting to a central unit, the same disadvantages of memory size, processing power, and failure possibilities, as discussed above, are apparent. In addition, another disadvantage is the possible failure of a remote unit and its phone line interface. Since it does not operate independently, it must be directed by the "head end". With a problem in the phone line interface, the unit would not be able to be directed and it would fail completely. As seen in all these examples, the dependence of the subordinates on the "head end" contribute to a less reliable system, and reduced performance.

## COMMUNICATIONS MEDIA

A number of different types of communications media are available for use in a building management system using a local area network. Media types such as twisted-pair wires, phone lines, and other existing wiring (such as PBX systems) can all be used. Since the pros and cons of each type of media are well known, they will not be discussed here.

One media, not yet discussed, that a LAN system can use and that a distributed system cannot, is another local area network. If a LAN already exists in a building, or building area, and the BMS electrical interface is compatible, or can be made compatible, both the existing LAN and the BMS LAN can coexist on the same medium. This can reduce installation costs in large buildings or corporations. But this does not mean that one large LAN will result. The two LAN's remain independent of each other, sharing only the common communication medium. For example, if an office LAN and a BMS LAN were to reside on the same medium, a unit in the office LAN typically would not share data with a unit in the BMS LAN.

## REAL LIFE EXAMPLES

The examples discussed in this section are descriptions of the operation of the Vanguard I Facilities Management System produced by Advanced Micro Systems Corporation. The examples show the sharing of information between units for control strategies, the sharing of resources ( in this case a printer ) between units, and load management operations for multiple units controlling one building.

The first example of operation uses the same two unit configuration controlling the building wings and the parking lot, as described above. This example shows control strategies using shared information. Let's assume that Unit One monitors the outdoor air temperature and humidity, and that Unit Two uses this information in its control schemes. Unit One will first detect a change in the outdoor air temperature and update its memory with the new information. It will also check to see if the information is needed by another unit on the network. It will find that another unit does need the information, and it will send a message containing the new temperature to Unit Two. Unit Two will receive the message, and recognizing it as a change in a sensor, it will check its control strategies to make any necessary changes to its controlled points. In this example, both units operate independently in the control of their building areas. The only dependence is the sharing of information monitored by one unit that is used by both units.

The next example uses the configuration of multiple remote systems reporting to a central office via phone lines. Let's assume that a remote unit must send a report at a specific time to the central office for printing. When the time arrives, the remote unit collects the data, formats the report and stores the information in its memory. The remote system phones the central unit and requests the printer for a report. When the request is granted, the remote unit sends the report information to the central unit, where it is stored in memory. When the transfer of report information is complete, the remote unit will release the printer. The central unit, upon detection of the printer release, will terminate the transfer and print the report. If another unit were to phone a print request during the operation just described, its print request would be denied until the data transfer for the first report was completed. The other remote unit would continue trying its print request until it was granted. Once granted, it would then proceed to transfer its report information. In this example, the remote unit continues to operate independently of the central unit while it transfers the report information. A delay in the granting of the print request will only delay the printing of the report, not the collection of the report information.

The final example of system operation is Load Management via a Local Area Network. Let's go back to the example of two units in the network, and assume this time that Unit Two monitors the electric meter. When meter information changes, Unit Two will update its data base with the new electric demand. If load control is needed, it will find the priority list of loads to shed, and will shed a certain amount. It will also send a message to Unit One instructing it to shed a certain amount from the same priority. Both units shed the appropriate amount to control the electric demand. In this example, each unit on the network controls its own loads. The only dependence is the message from Unit Two to Unit One sending the shed amount and the shed priority. The actual shedding of the loads is performed by the individual unit. Also, the unit directing the load control does not need to know about the loads controlled by the other network units. The load control occurs without the directing unit needing to know the size or type of system that it is controlling. In this example, the message exchange mechanism allows Unit Two to direct Unit One to perform load control without knowing anything about the loads that Unit One controls.

## CONCLUSIONS

As seen in the previous sections of this paper, the Local Area Network architecture allows each member of the network to operate independently. This independence gives the LAN system a number of advantages in reliability that a distributed system does not have. First, a failure of one unit will only minimally affect the other units, and may not affect those units at all. A failure in a distributed processing system, on the other hand, can cause the entire system to fail.

Secondly, the amount of communications between the units on a LAN during normal operation is much less than the amount of communications on a distributed processing system. This is because the constant updating of the "head end" memory does not exist in a LAN system. The lower communications traffic contributes to a more consistent system performance. Thirdly, less memory is needed by units on the LAN reducing the cost of the LAN system. Less memory is required because each unit needs only enough memory to control its area.

And, finally, fourth, the LAN architecture is easily expandable in that it allows any number of units to be added to the total system without affecting the performance of any one unit. Expansion of a distributed system means more work for the "head end", creating a bottleneck, and reducing system performance. It also means that more memory and storage is needed at the "head end" to keep all the point parameters for all the distribution units, increasing the hardware cost of the system. And, as pointed out earlier, a greater amount of storage and processing requirements increases the chances of a system-wide failure, reducing the system reliability.

When adding together the advantages such as the independence of units, easy expandability, fewer possibilities for bottlenecks, and information and resources shared when needed, the application of Local Area Networks in Building Management Systems becomes very attractive. These facts, when added together, show three main areas where LAN systems are superior to distributed systems: reliability, flexibility, and performance. The LAN architecture offers these advantages while reducing or eliminating the problems found in distributed systems.

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