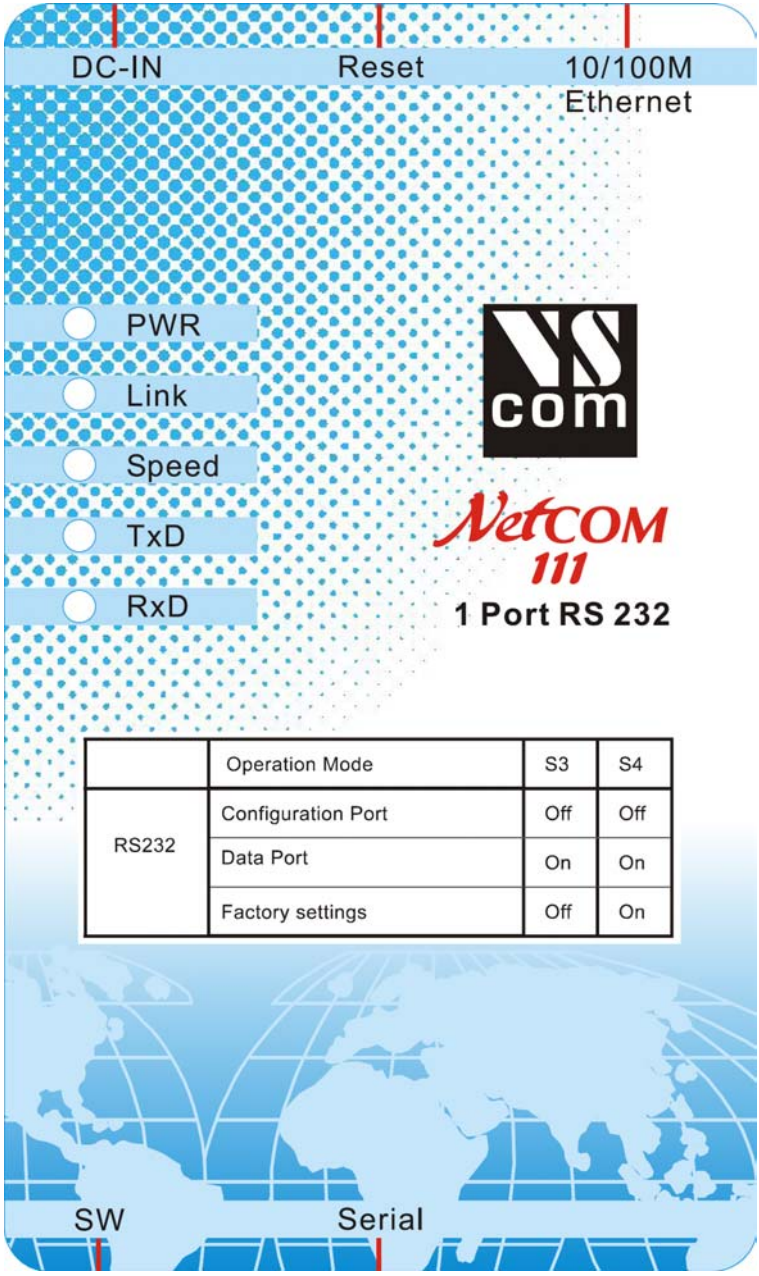
Remote Serial over IP

Introduction on Serial Connections via IP/Ethernet



	Operation Mode	S3	S4
RS232	Configuration Port	Off	Off
	Data Port	On	On
	Factory settings	Off	On

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INTRODUCTION

NetCom Devices provide support to bring old fashioned and costly machines to networks. The target is to still have the benefits of those long-term devices in the future, and combine these with the benefits of general spreading networking technology.
The combination of such technologies brings additional possibilities never seen before.

This document is intended to explain the terminology, the different techniques and options to interested persons. Also the different point of views on the functions have their topic here. The described functions are not necessarily implemented at time of writing.

CLASSIC STYLE OF COMMUNICATION

In the past time many machines and devices have been equipped with embedded information technology. This happened with simple sensors, up to huge plants of NC machinery. All these devices required some kind of data connection. In most cases a serial interface has been chosen to exchange data. Especially the asynchronous RS-232 became very widespread. It is a very simple interface in terms of cabling, function and implementation.

When the installations grew from single machines to halls full with equipment, the cabling became more difficult. The limitations of RS-232 could not fit the requirements. Other standards have been implemented, namely RS-422 and RS-485, and also a family of field busses. Today there is a variety of such systems on the market and in use.

Each system has its own requirements for cabling and protocols. If a new device has to be installed, it is necessary to search for a suitable connection to the already installed data communication systems. In many situations this requires adapters for the serial ports of a computer.

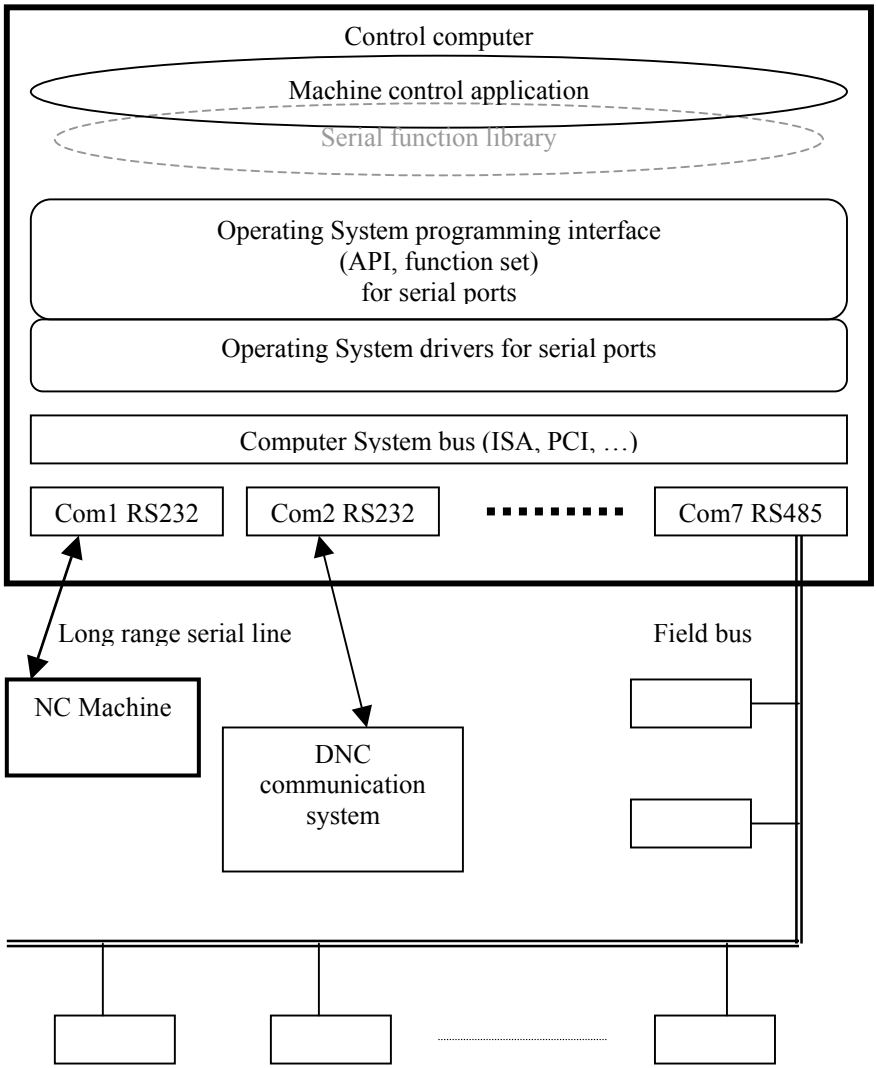

Image 1: Classical communication structure

ETHERNET AND INTERNET TECHNOLOGY

In offices the data transmission via Ethernet is now the de-facto standard. Ethernet has seen some major steps in development. Nowadays it can be transmitted via copper cables, optical fibres and even wireless by radio transmission. It is available in speed ranges beginning at 2 Mbit/s up to 10 Gbit/s. In the same development time the reliability has been improved significantly.

But the strongest force to advance the usage of networking has been the Internet technology. The Internet Protocol (IP) is designed for transport over different data carriers. This is the base for all today networks. The transport over Ethernet has been implemented right from the beginning. Today it is very well understood. And by connecting a local network to the Internet, the devices can send data to virtually everywhere on the world.

Ethernet with its tree-like structure is very effective. Simple (and single) cables connect locations together, while many devices can use this connection at the same time. This technology becomes accepted also in industrial environments now.

NETWORK-CONNECT EXISTING DEVICES

There is a movement to Ethernet now. But the point is to connect already existing machines or sensors to Ethernet. This can be hard, costly or even impossible. A direct connection to the network requires a modification of the machine. This is the installation of additional hardware, more processing power, as well as special drivers. And this solution is specific for only this machine, it can not be used for all other machines.

Serial over IP offers a different approach. Instead of implementing an Ethernet port in the device, the device remains unchanged. Even in the Ethernet era the device communicates via its classic serial port. But the NetCom server brings the controlling serial port forward to the machine, far from the computer. This NetCom server is controlled from virtually everywhere. The network software in the NetCom server and in the operating system of the controlling computer hides all the transportation details from the application programs.

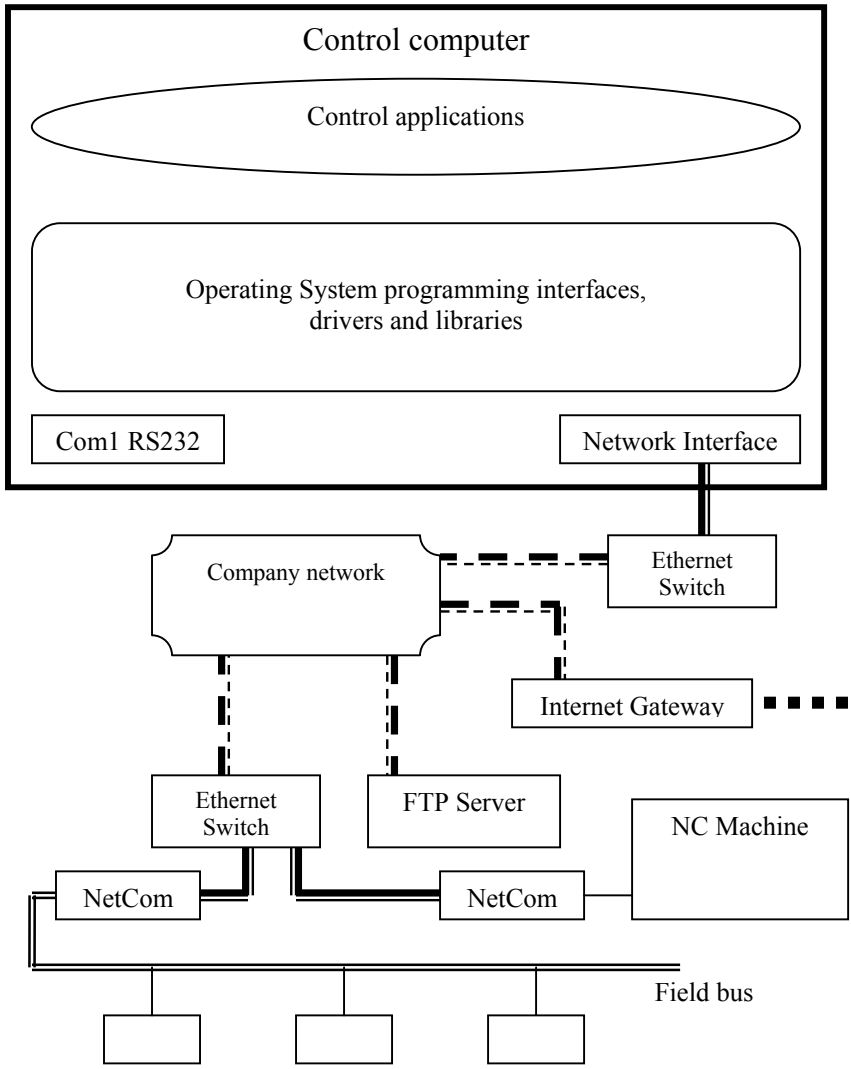

Image 2: Network communication structure

Using Internet technology in an existing installation allows a common programming interface to all devices and stations/servers operating in this environment. New applications are designed to use the network directly; they are IP-enabled. Those systems and applications can communicate with as many machines and computers as necessary. Plus it does not require any change in the hardware of the computer.

SERIAL OVER IP

Connecting serial devices over IP-networks is always done in the same way, in terms of hardware installation. The machine has a serial port, this is connected to a device like NetCom. The NetCom connects to the Ethernet installed near the machine. When it is configured, it is accessible via IP. Applications running anywhere can connect to it. And this way they connect to the serial device.

Depending on the type of control application there are different point of views to the installation. Basically they are divided into "Driver mode" and "Raw-IP mode". Both modes are described further in this document.

DRIVER MODE

In a classical installation for remote computers, the computer has a built-in serial port (often named Com1). This port is attached to the system bus (ISA, PCI, …) of the computer. The serial connector (DB25 or DB9) is available at the case of the computer. For long-range data transmission some special cabling and even transceivers are attached to the port of the computer and the serial device far away. For each controlled serial device the computer has another serial port (Com2, Com3, …) and more cables to the serial devices.

Serial over IP reduces this equipment drastically. An additional virtual serial port is installed in the computer, often as Com3. One can think of this Com3 as a serial port attached to a special kind of "system bus". This bus is available over network from the computer. It is very long; it reaches to every location accessible via IP. On one end of this system bus (near the serial device), there is a serial port. This is the serial port installed as Com3.

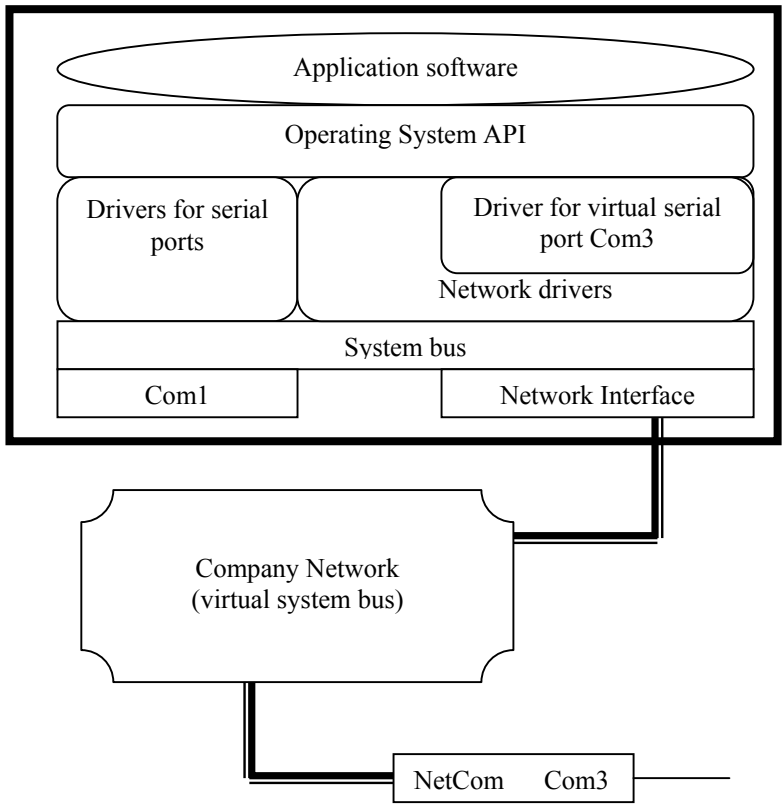

Image 3: Driver Mode structure

In the classical situation the control application communicates via Com1. In reality this means it calls some driver functions to perform the communication task. The driver is responsible to perform the required operations via system bus. The serial data is sent through the long cabling to the device.

An installation with NetCom behaves quite similar. The application uses some driver functions to perform the communication tasks. The driver is responsible to perform the required operations; but this time over network. The driver will use the network drivers, but this is invisible (and not important) to the application. The data is transferred via IP-Network to the serial port of NetCom. There it is available as usual serial data on the cable to the device.

As the overall result there is minimum difference between the classical installation and the NetCom connection. The only change for the application is to use Com3 instead of Com1. This shouldn't be a problem, since applications are configurable. And it is also possible to install the NetCom as Com1. There is also no need to change anything in the serial device.

The computer is not restricted to one serial port or one NetCom device. The only limit for virtual serial ports is the limit in the operating system. In Windows 95 to ME this is a maximum of 128 serial ports, in Windows NT and 2000/XP it is 256. Since there is no expensive hardware installed in the computer, it is easy to have a backup or redundant system, and run it in parallel.

Classical	NetCom
One connector per controlled device; more interface boards for more ports	All connections through the same single existing network interface
One cable per connected device	Single common network cable
Cable length limited by RS-232 or RS-422/485, or by other transceiver technology	Unlimited distance by data transport via TCP/IP (Internet technology)
Doubled hardware costs for backup systems	No special hardware required for backup systems

TCP RAW MODE

In the TCP Raw mode the applications establish a direct connection to other applications. The applications operate with network functions by themselves, without a virtual serial driver. To communicate they use a data structure describing the connection. On most operating systems this structure is called a *socket*. Therefore the TCP Raw Mode is often called the "Socket Mode".

The NetCom acts as an Internet server. It is permanently waiting for incoming connections. When used in driver mode, there are two simultaneous connections. One transports control information, while the other is for the serial data.

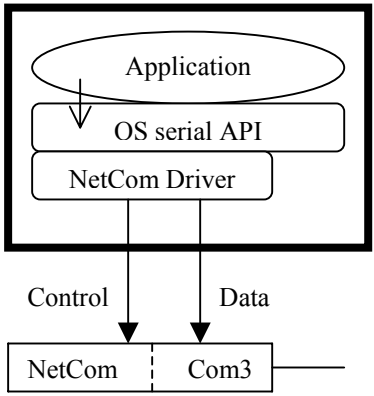

Image 5: Driver Mode connections

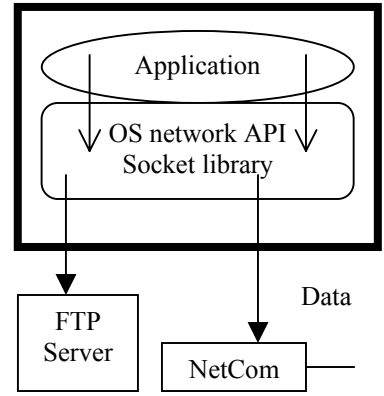

Image 4: Raw IP mode connections

In TCP Raw Mode only the Data connection is used. The parameters of the serial port (speed, parity, …) are predefined by configuration. When a connection comes in, all data received is sent to the device at the serial port. All data received over the serial port is transferred to the connected system via network. There is no difference to access any other type of servers like FTP. Because the NetCom acts like other Internet servers, this is called TCP Raw Server Mode.

The serial device is now network enabled. If this shall be done via implementation in the device, an Ethernet port has to be installed to the internal system bus. Certain drivers for network and IP-access are necessary. Depending on the device this can be very expensive.

With NetCom the device remains unchanged. It seems to have an external system bus at the serial port, connected to IP-Networks.

Control Applications take profit of network features. Connections to devices are opened on demand. The device is accessed via its IP-Address or a symbolic name available via a DNS database. Different applications on different computers can access the device.
Plus it is not necessary to install a driver on the system.

The firmware of the serial device can also be enhanced. In same cases the direct implementation of an Ethernet port and TCP/IP is too expensive. But the device can operate the known protocol HTTP over the serial line. Together with NetCom this device is a web server, and an ordinary browser can access it. This can be convenient for many customers.

Driver mode	TCP Raw mode
Installs virtual serial ports	Does not require a driver
Supports existing dedicated applications	Supports all devices by common interface
Special features in Windows (and Linux)	Available for all networked operating Systems

VARIATIONS OF THE BASIC MODES

Driver mode and TCP Raw mode are not fixed terms. There are variations in them. Different communication tasks require different settings. The options of NetCom are targeted to fit in nearly every communication environment. Here is a short list of the sub-modes described later.

- TCP Raw Client
- UDP communication
- Null Modem tunnel
- IP Modem

TCP RAW CLIENT MODE

In the description of the TCP Raw mode the NetCom was used as a server station. The NetCom is accessible in the network. It is in "Listening" state waiting for a TCP connection to come in. With this connection it opens a transparent tunnel for the serial data.

In the related TCP Raw Client mode the function of the communication partners are reversed. The controlling computer is in "Listening" state, waiting for incoming connections. The NetCom is configured to establish and terminate this connection on special circumstances. In most installations the NetCom is configured to open the connection when data has arrived on the serial port. The data is transferred to the server computer. And when no new data arrived for a specified time, the connection is closed.

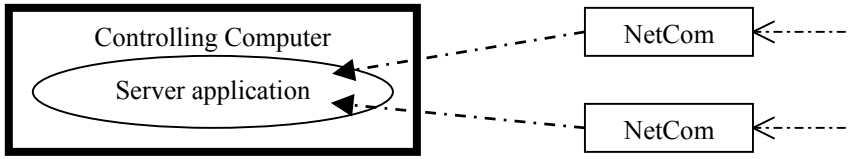

Image 6: TCP Client Mode

This may be handy for observation of sensors sending data once in a period of several minutes. The connection is opened by NetCom, and closed if no more data is received for e.g. 2 seconds. The controlling computer only needs to collect the data. It is not required to actively

open all simultaneous connection to each sensor. Nevertheless the sensor data arrives in real time.

In contrast to some other products, NetCom is still available in TCP Raw Server Mode or even in Driver Mode, when the client connection is actually closed. The operation mode adapts to the actual situation.

UDP COMMUNICATION

TCP connections are reliable. The transmission and reception of data is guaranteed. This reduces the burden of secured protocols in the applications. However there is some overhead in transmitted data. When sending small packages of serial data (e.g. temperature sensor) in TCP Raw client mode, this overhead may be more then the total amount of data sent.

UDP is not secured like this. The data to send are stored in an IP frame as UDP data, and sent out. There is no guarantee for delivery. But the data is sent relatively fast. If the network which transports the data is reliable, or some packet loss may be tolerated, then UDP is an option. The data is sent out faster, the NetCom is immediately free for other operations; it does not wait for the computer to accept the data.

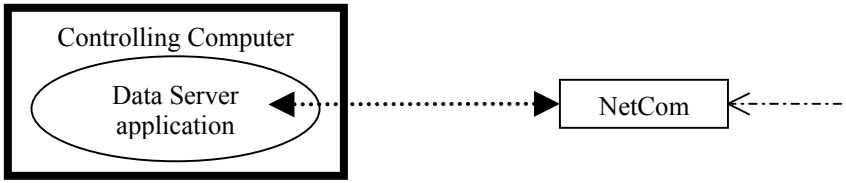

Image 7: UDP Communication

Since all communication partners must operate in the same way, there is not a difference between a “Server” and a “Client”. These phrases may be used on the application level, one station offers data and another consumes that. But on the IP level they operate in the same way. So this mode of NetCom makes no distinction about Server or Client; hence it is named UDP Communication.

NULL MODEM TUNNEL

This is a variation of the driver mode. Two NetCom communicate with each other. Data received on the serial port is sent to the other device via the network. At the second NetCom the data is sent again over the serial line. So far this is the same as a pair of two NetCom acting in TCP Raw Server and TCP Raw Client mode. But connected as such a Null Modem pair also the status and control signals (RTS/CTS, DTR/DSR) are transferred between the two NetCom. The connection of the two NetCom via the Internet operates like a serial Null Modem cable. The only difference is the fixed serial speed at both sides. An automatic speed detection is not reliable for every configuration and transmitted data. But the advantage is, both ends of the connection do not need to operate at identical serial settings. In rare cases it may be useful if the configuration is different.

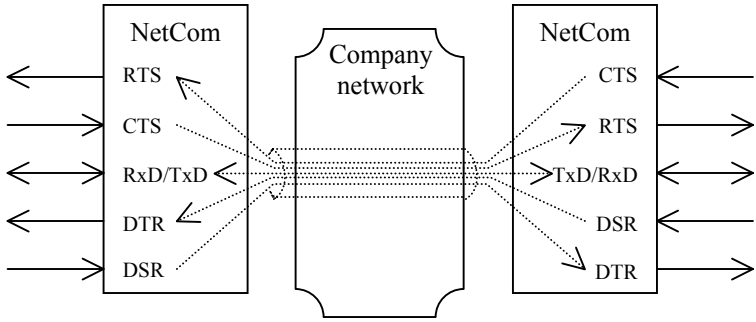

Image 8: Null Modem tunnel

If there is a machine or computer, with no chance to implement network technology, this operation mode is a choice. The software does not need a change, the communication is still via the serial port. But instead of placing the communication partners together (less than 40ft with RS232) or use special long range cabling and drivers, all this is replaced by two NetCom. Both systems are unchanged, no extra cabling is required.

IP MODEM

(Formerly named “Internet Modem”).

In some installations the long range problem has been solved by using Modems. One Modem is installed near each controlled device/machine. And the controlling computer also has a Modem. The software dials to the device via the company phone system. This way one computer and application can control many devices.

With NetCom the phone system is replaced by the company network (or even the Internet). The application has a list of phone numbers to dial. These ordinary phone numbers are replaced by the IP-Addresses of the NetCom at the controlled devices. The NetCom at the computer establishes a TCP connection to the devices, thereby acting like a Modem. Dialling is done via standard AT commands, there is a CONNECT response, and so on.

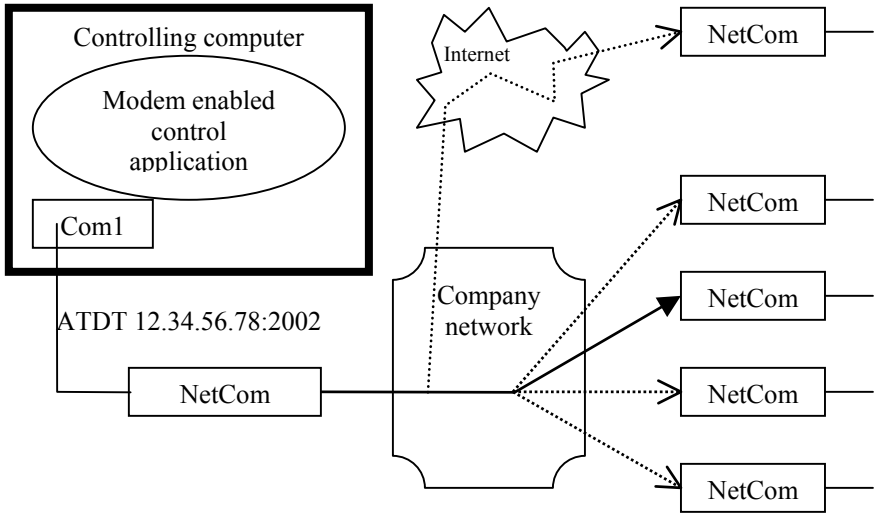

Image 9: IP Modem

The computer still controls a lot of devices. The range of connections is extended via the Internet. So one computer can control more devices than before. The application is unchanged.

Situation	Solu tion
Computer running Windows or Linux, existing application operating via serial ports	Driver mode
Computer has TCP/IP functions, new software has to be implemented	TCP Raw Server Mode
Computer must monitor several stations, low amount of data	TCP Raw Client Mode
Computer must monitor several stations, reduce network overhead, some data loss is acceptable.	UDP Communication
Computer and device have no network	Null Modem tunnel
Computer has no network function, but must control several devices	Internet Modem

GLOSSARY OF TERMS

APIPA: Automatic Private IP-Addressing
A scheme to self-assign an IP-Address to a network device. The device selects an address of the LINKLOCAL range 169.254.0.1 to 169.254.255.254 by random. If this address is unused, it assigns it to itself. Otherwise the next address is tested. It became widespread with Windows 98.
The netmask is 255.255.0.0, the addresses are not routed on the Internet.

ART: Automatic Receive Transmit control
Special control for RS485 modes. In RS485 the line driver for transmitting must be disabled (tri-stated) when the device does not send data. In a 2 wire configuration this is known as data direction change, with 4 wire it is called line contention.

DHCP: Dynamic Host Configuration Protocol
A service used to retrieve an IP-configuration from a database.

FTP: File Transfer Protocol
A common protocol to access a file server.

HTTP: HyperText Transfer Protocol
The protocol used by web browsers to access a web server.

Internet: The net connecting networks
A set of protocols to exchange data between different networks. These information's are carried via a global network of fibres and satellite links.

IP: Internet Protocol
The basic definitions for data packages. These Internet frames are stored and transported embedded in data frames of the local network.

IP-Address: Internet Address
The Internet address is noted as a group of 4 decimal numbers. Each station on the Internet has a unique address. Some ranges are reserved for private networks, not connected to the Internet.

LINKLOCAL:
This is a reserved address range for private (i.e. not connected to the Internet) networks. Designed for small number of stations. Used with APIPA.

NAT: Network Address Translation
A technique to have a private LAN share one public IP-Address. With NAT the transport information in IP-frames is exchanged by the public data of the NAT-Router.

Netmask: Groups stations to a Net
The AND-operation between the IP-Address and the Mask is an important value. When to stations have identical value here, they are “in the same net”. Which means they can communicate direct, without transmitting to a Router.

PAT: Port Address Translation
A technique to share a public IP-Address by many internal servers on private addresses. The target address and port is exchanged with values stored in an internal table. Mostly used together with NAT.

Router: Transmits data over the Internet
The backbone devices of the Internet. Routers connect two networks together. On one side they receive data frames containing IP-data. They extract these data, and send them on another side; there also stored in data frames of the second network. Typically they connect more than two networks. The basic task is to decide which route the IP-data must take now.

RS-232/V.24: common serial transmission
Characters are sent as separate bits, timing is well defined. The medium is copper cable, using typical +/- 12 Volt. Each signal is defined related to a common ground; one wire per signal plus GND.
RS-232 is a point-to-point connection.

RS-422: Industrial serial transmission (multidrop)
A transmission method with differential signals. Allows higher speed, longer cables and is resistive against electrical noise. RS-422 allows for up to 16 receivers. The transmission is via twisted pair copper cable using differential signals. Sender and receivers must share a common voltage range (max. +/-7Volt difference). Two lines per signal, plus common GND.
RS-422 is a point-to-multipoint connection.

RS-485: Industrial serial transmission (multipoint)
The signals and cables are the same as RS-422. The transmitters can go tri-state. Several stations can send data on the same lines, at different times.
RS-485 is a multipoint-to-multipoint connection.

SNMP: Simple Network Management Protocol
A general purpose configuration system. Devices understanding SNMP may be configured and monitored.

TCP/IP: Transmission Control Program/Internet Protocol
TCP establishes connections between two partners via the Internet. The data is sent in IP-frames, each frame is acknowledged be the recipient. Lost packages are repeated.
Software using TCP has a secured transmission; the delivery of the data is guaranteed.

UDP: User datagram protocol
Similar to TCP the data is sent in IP-frames. But in opposite there is no connection or acknowledge by the recipient. The transmission is faster for small data, but data can get lost.
Software using UDP must handle the related problems.