MODERNIZATION OF AUTOMATIC SURFACE WEATHER OBSERVING SYSTEMS AND NETWORKS TO UTILIZE TCP/IP TECHNOLOGY

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ABSTRACT

The built-in TCP/IP technology of Vaisala Automatic Surface Weather Observing Systems gives the national meteorological and hydrological services a great possibility to utilize the benefits of the latest information technology where one single communication protocol is used to harness the heterogeneity of different telemetry standards and data collection procedures. The TCP/IP provides a reliable delivery of real-time weather observations at lower operational costs, and thus, enables the organizations to achieve the objectives of higher efficiency, improved data quality, and spatially dense observations. By using the in-built TCP/IP communication protocol over a large number of different telemetries, such as Ethernet, serial links, cellular modems and satellites, the observation network operator can enjoy not only the benefits of redundancy but also the economies of scale and scope by reducing significantly the complexity and cost of the network design.

1. INTRODUCTION

The Internet Protocol Suite (TCP/IP) is the set of communications protocols used for the Internet and other similar networks. Being the most widely used network protocol suite used around the world the TCP/IP offers a great possibility for the national meteorological and hydrological services to take into use one single communication protocol to harness the heterogeneity of different telemetry standards and data collection procedures. Aligned with the division of the protocol suite into layers of general functionality the TCP/IP utilizes encapsulation to provide abstraction of protocols and services. Each layer solves a set of problems involving the transmission of data, and provides a well-defined service to the upper layer protocols based on using services from some lower layers. Upper layers are logically closer to the end user and deal with more abstract data, relying on lower layer protocols to translate data into forms that can eventually be physically transmitted. The most important protocols of the TCP/IP are the Transmission Control Protocol (TCP) and the Internet Protocol (IP).

2. BUILT-IN TCP/IP CONNECTIVITY IN VAISALA AUTOMATIC SURFACE WEATHER SYSTEMS

When fully utilizing the built-in TCP/IP connectivity in Vaisala Automatic Surface Weather Observing Systems the whole mindset of using automatic weather stations (AWS) as a part observation network changes radically. A conventional data collection system is typically based on slow and complex data polling procedures and dedicated lines with limited capabilities to provide large amount of surface weather observation data from a large number of remote AWSs spreaded around the observation area. Instead the built-in TCP/IP connectivity enables the users to implement a network management system where the AWSs are truly an integral part of the whole monitoring network providing a two-directional connectivity from the AWSs to the central site and back similar to other embedded systems like data servers, switches, routers or hubs required to control the data streams of the Internet network. When the two-directional communication method within the TCP/IP is taken into use it gives the end users significant possibilities to automatically manage the observation sites of the monitoring network. For example, the initial configuration or the configuration updates to a large number of observation sites can be fully automatized, or it is possible to quickly change the operational parameters of the monitoring network without losing any valuable measurement data.

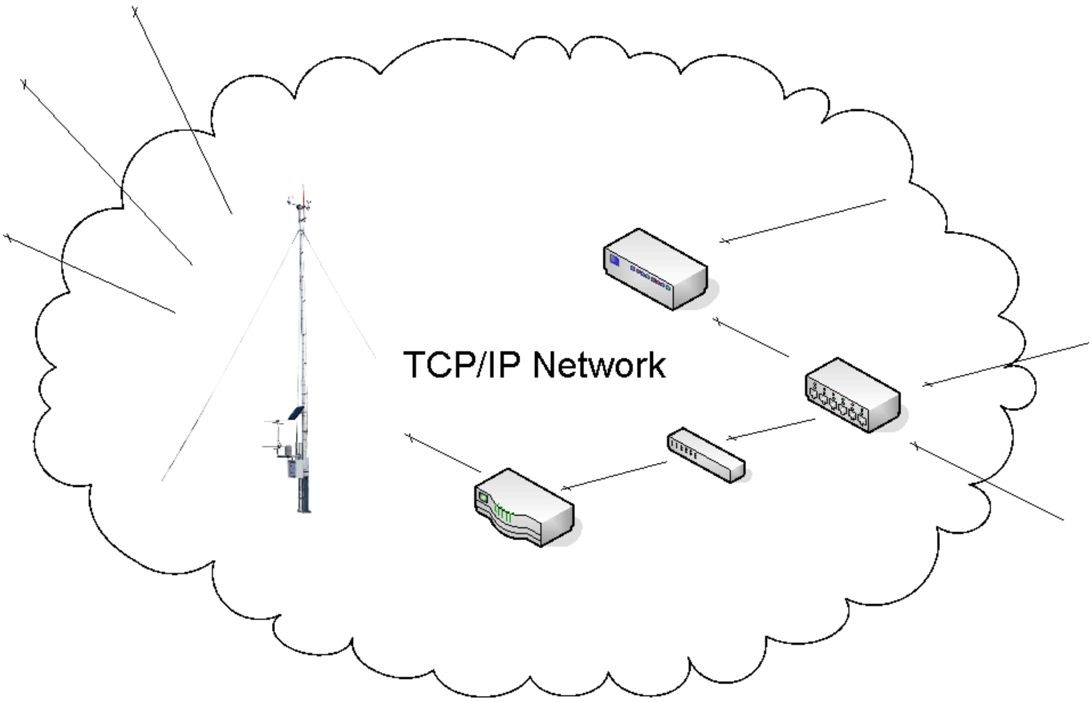

Fig 1. Vaisala AWS as an integral part of the Internet network used as an intelligent TCP/IP sensor interface

The AWSs with the TCP/IP protocol stack embedded start to remind a general-purpose computers being able to do number of different tasks depending on programming and using the same architecture and software components. In addition to low power consumption, a wide operating temperature range, and a compact data logger design based upon long-term expertise and in-field experience, Vaisala Automatic Surface Weather Observing Systems support fully the TCP/IP communication model. From the lowest to the highest, the four layers of the Internet Protocol Suite utilized by Vaisala AWSs are the Link Layer divided into the Data Link Layer on top of the Physical Layer, the Internet Layer, the Transport Layer, and the Application Layer as shown in Figure 2.

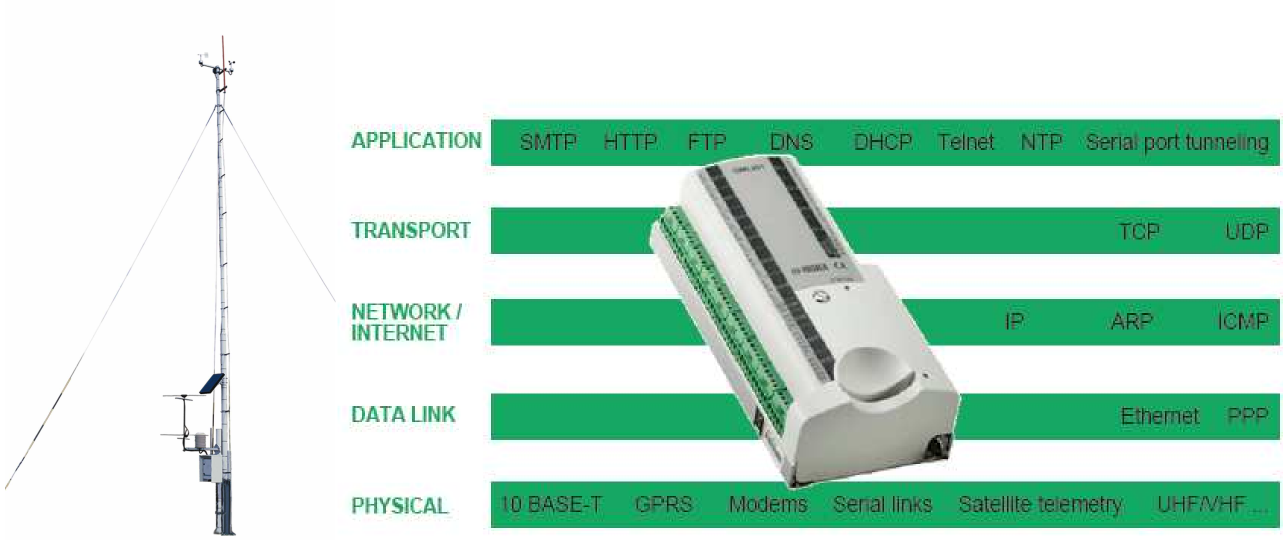

Fig 2. The four layers of the Internet Protocol Suite built into Vaisala AWS

The IP is the primary protocol in the Internet Layer of the TCP/IP and has the task of delivering datagrams or packets from the source host to the destination host solely based on its address. For this purpose the Internet Protocol defines addressing methods and structures for datagram encapsulation. The TCP operates at a higher level, concerned only with the two end systems. In particular, the TCP provides reliable, in-order delivery of a stream of bytes from one program on one computer to another program on another computer.

Among its management tasks, the TCP controls message size, the rate at which messages are exchanged, and network traffic congestion. The Transmission Control Protocol (TCP) is the core protocols of the Internet protocol suite providing reliable, in-order delivery of a stream of bytes, making it suitable for applications like file transfer and e-mail.

The Address Resolution Protocol (ARP) is the standard method for finding a host's hardware address when only its network layer address is known. ARP is primarily used to translate IP addresses to Ethernet and other LAN technologies. The Internet Control Message Protocol (ICMP) is one of the core protocols of the Internet protocol suite. It is chiefly used by networked devices' operating systems to indicate that a requested service is not available or that a host or router could not be reached. The User Datagram Protocol (UDP) enables programs on networked devices to send short messages faster and more efficient than TCP in applications like Domain Name System (DNS) that do not need guaranteed delivery.

The Application Layer built into Vaisala Automatic Surface Weather Observing Systems provides many different options for the end users to transfer data. The Simple Mail Transfer Protocol (SMTP) is a client-server protocol using the standard for e-mail transmissions across the Internet whereby a client transmits an email message to a server. The Hypertext Transfer Protocol (HTTP) is a communications protocol used to transfer information on intranets and the Internet between a client and a server. The HTTP get request is supported to provide the measured data simply and directly to your web browser. The File Transfer Protocol (FTP) is one of the most common practices to transfer data from one device to another over the Internet or through a network. The Telnet (telecommunication network) is a network protocol used on the Internet or local area network (LAN) connections supported by the majority of network equipment and operating systems.

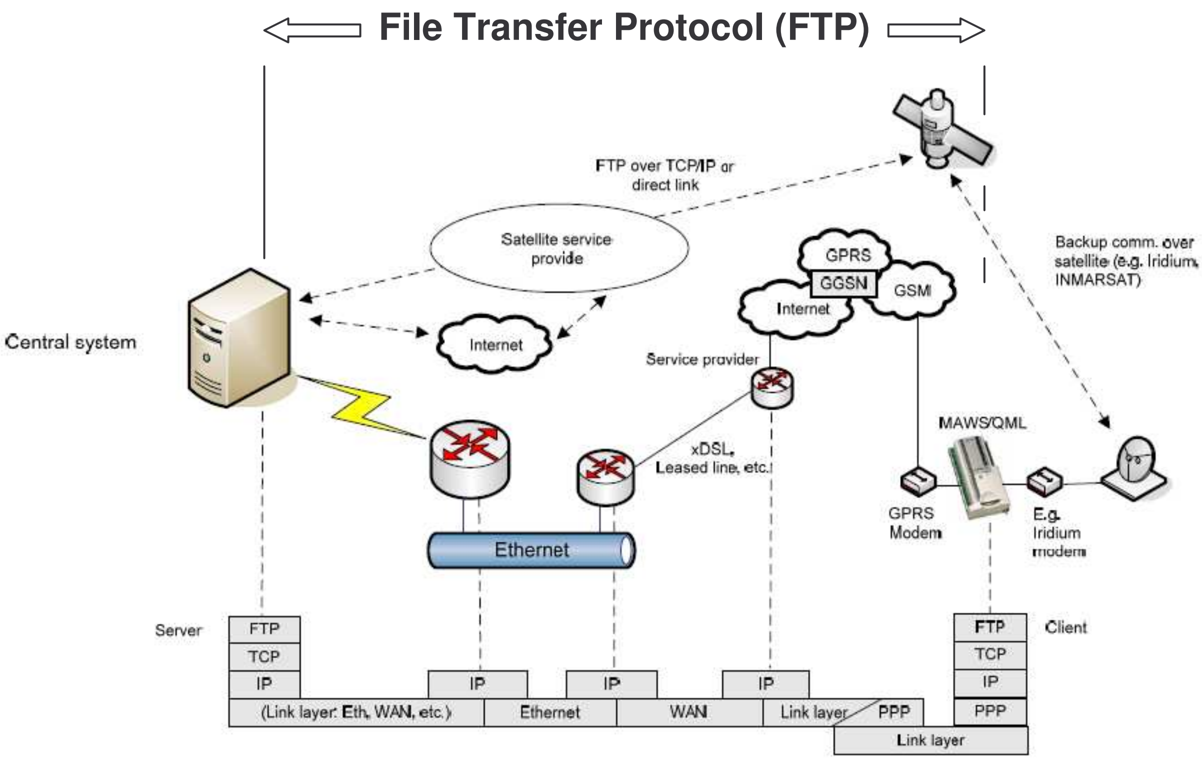

Fig 3. *The Internet Protocol Suite simplifies data collection procedures at the central site - one data transfer protocol (FTP) used between the client (AWS) and the data collection server over multiple different physical data transmission media*

The Domain Name System (DNS) makes it possible to assign Internet names independently of the physical routing hierarchy represented by the numerical IP address. The Dynamic Host Configuration Protocol (DHCP) automates the assignment of IP addresses, subnet masks, default gateway, and other IP parameters. The Network Time Protocol (NTP) is a protocol for synchronizing the clocks of computer systems over packet-switched data networks, and thus, no additional hardware is required to synchronize the data of the observation sites.

The serial port tunneling means the use of multiple virtual serial ports, i.e. redirectors capable of emulating all serial port functionality over Ethernet. In other words, a large number of virtual communication ports can be used for data transmission, service access and additional sensor options utilizing the TCP/IP, splitting one Ethernet communication port to a large number different virtual serial ports. When a virtual serial port is used the redirector makes an IP network connection to a device server at a specified IP address and TCP port number that corresponds to a remote device on the server.

The Point-to-Point Protocol PPP is a data link protocol commonly used to establish a direct connection between two nodes over serial line, modem line, phone line, cellular telephone, specialized radio links, satellite links, fiber optic links and others. Supporting the PPP with the Challenge Handshake Authentication Protocol (CHAP) and the Password Authentication Protocol (PAP) Vaisala Automatic AWSs are not bound to use only one specific physical data transmission medium, and thus, ensure data throughput via variety of different communication telemetry links if needed.

3. BENEFITS OF UTILIZING BUILT-IN TCP/IP IN SURFACE WEATHER OBSERVATIONS

The TCP/IP provides a reliable delivery of real-time weather observations at lower operational costs, and thus, enables the organizations to achieve the objectives of higher efficiency, improved data quality, and spatially dense observations.

Utilizing the latest capabilities of the high-speed Internet network the AWSs can distribute large amounts of real-time data to the central site for further processing in a matter of seconds. Complex data processing from large amount of metadata can be easily done by the central site with adequate system resources available while the data processing at the observation site can be simplified to its minimum saving costs in maintenance activities and system upgrades. On the other hand, it is also possible to build AWS networks with different topologies, even peer-to-peer networks, so that the AWSs communicate directly without using any central station. Such an approach is beneficial especially in cases like wind towers or semi-automatic weather stations where a large number of different observations and measurements are combined together through a high-speed local area network (LAN) representing one uniform observation site in a larger countrywide network, or when the measurements from an individual AWS is cross-checked and possibly amended by the data measured by the neighbouring AWSs close to the site. Ultimately, the data logger in the TCP/IP network can function only as an intelligent interface and cost-efficient contact point to Internet both for the conventional analog and serial surface weather sensors.

With the TCP/IP protocol stack embedded into the data logger the user can connect the observation sites directly to TCP/IP networks using variety of media, such as Ethernet, serial links, radios, modems and satellites, without any external serial to TCP/IP adapter modules. This means not only lower costs in hardware expenses and better robustness at the system level but also a possibility to configure one of the TCP/IP sockets of the data logger to use multiple different end-user applications, such as e-mail (SMTP) or web browser (HTTP), used all at the same time. Thus, instead of using expensive external modules providing the TCP/IP connection capability to be used only with one higher level application at a time, the TCP/IP functionality built into the data logger gives the end user significantly better possibilities to utilize one hardware unit for variety of different applications to be used simultaneously by a large number of different end users.

Due to its scalability by nature the various upper level routing protocols makes the TCP/IP based systems not only suitable for point-to-point connections but also for large real-time networks with even thousands of observation sites connected where an individual site can locate practically anywhere in the world. When using the TCP/IP the importance of the physical transmission link diminish greatly due to the fact that virtually the whole telecom industry is moving towards TCP/IP based backbone network from traditional switched networks when the transition to 3G and 4G mobile networks evolve. Thus, just a standard web browser can be used to retrieve data from a single AWS to a mobile phone, computer or similar.

Since a large amount of real-time data is collected by the central site in the TCP/IP based networks the possibility to improve the quality of the observation data is also far greater than before. This is because the probable errors or quality problems can be discovered in an much earlier phase than when collecting the surface weather data with less frequent interval, e.g. once in an hour. Also, due to a spatially denser surface weather observation network providing a lot of real-time data within a short period of time the warnings or alarms are easier to generate whether it is about a sensor fault or other similar event.

One of the true benefits of the TCP/IP protocol suite is that it is capable of using new alternative routes for the data transfer and not only the existing ones. Thus, using multiple routes in a TCP/IP based surface weather observations network high data availability is achieved and the observation network operator can truly enjoy the benefits of redundancy without increasing the complexity or cost of the whole network design.

Since the TCP/IP is a global open standard there is a large number suppliers worldwide to provide equipment and accessories for different parts of the Internet network. Therefore, commercial, 3rd party routers and switches make it possible to build a TCP/IP network with best possible price, with no vendor lock-in risks. Additionally, there is a huge amount of available programs using the upper level protocols, for instance, emailing, file transfer, encryption of sensitive data, HTTP for web servers and clients. Even the services of building and maintaining the observation network can be done with local or global players. All this creates the end user of the observation network the possibility to enjoy the benefits the economies of scale and scope and cut down the overall costs when designing, operating and maintaining the surface weather network.

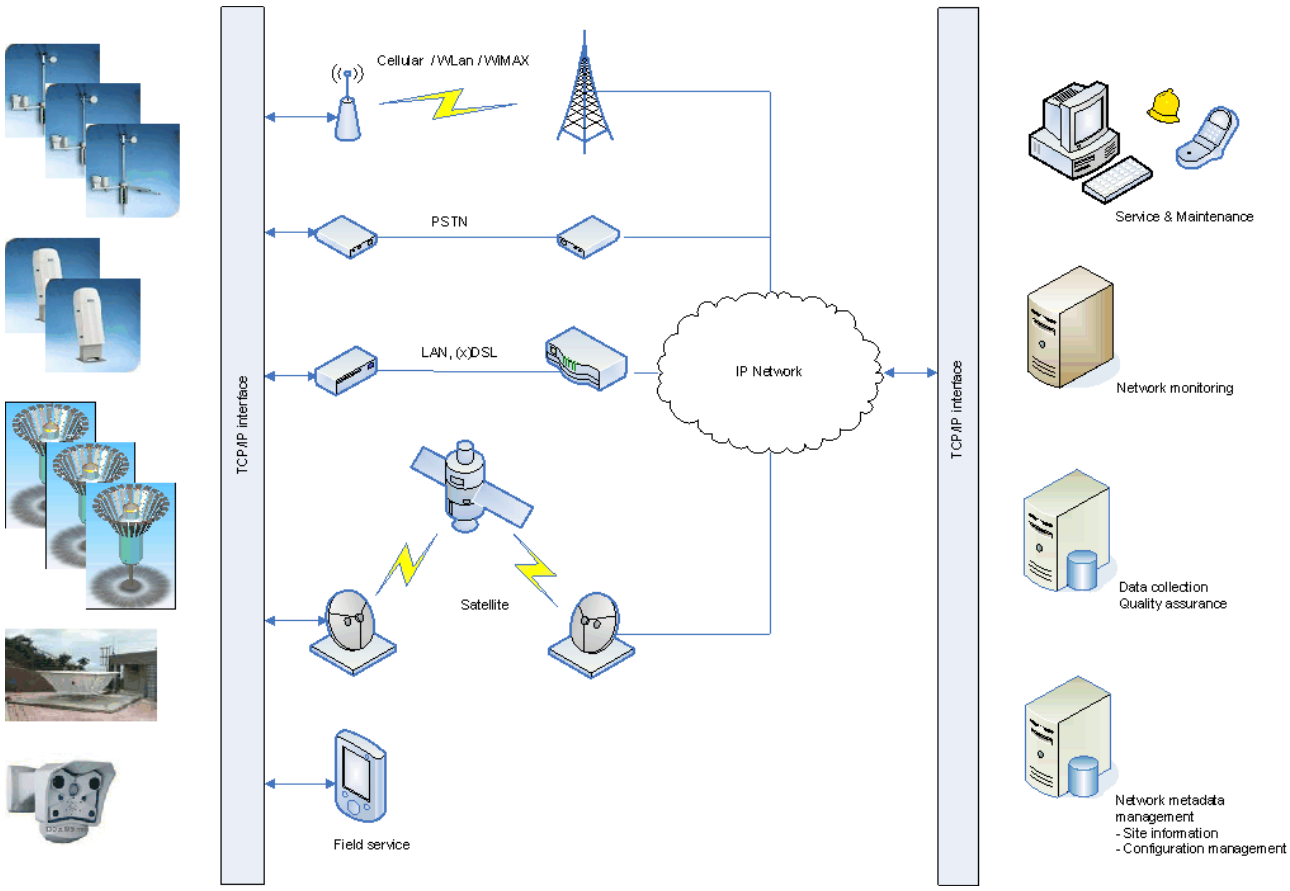

Fig 4. *Internet Protocol Suite used as a backbone for the surface weather observation network*

The TCP/IP based networks give also great possibilities for meteorological and hydrological institutes to take into use new technologies in surface weather observations. The high-resolution IP network cameras used for remote visual observations are one of the latest new technologies which gradually increase their significance as a part of surface weather networks making possible larger image areas with up to 360° panorama and accurate image processing and archival at the observation site. Another possibility is to implement Internet based specific standard families similar to transportation industry where the National Transportation Communications for Intelligent Transportation System (ITS) Protocol (NTCIP) has been created to provide both the rules for communicating (protocols) and the vocabulary (objects) necessary to allow electronic traffic control equipment from different manufacturers to operate with each other as a system.

4. SOLUTIONS TO IMPROVE DATA SECURITY AND NETWORK RELIABILITY

On a larger scale the TCP/IP network can be said to be more reliable than a traditional switched telephone network although occasional network breakdowns of the Internet highlight the need for redundant solutions where the data transfer from critical observation sites has at least been duplicated from one point to another. However, there are many large national or international or private TCP/IP based networks used daily by the governmental organizations, banks, insurance companies and others, which simply shows that in practice the TCP/IP based networks are almost impossible to knock down completely.

From the data security point-of-view, in non-mission critical observation networks the operator can rely on the TCP/IP infrastructure publicly available and use the public file transfer, time synchronization and web-hosting services where the initial purchase and maintenance costs are relatively small. The high availability networks being strongly mission-critical shall be based on a secured Intranet type of a network where basically all the services of the network are managed by the organization operating the network. Also, there are already many solutions commercially available to improve the Internet data security. The first and less expensive option to establish is the service provider model where the data security has been built locally using Private Access Point Name (APN). An Access Point Name (APN) identifies an external network that is accessible from a data terminal. By default, a SIM card in the data terminal is then configured with the APN of the service provider. The second possibility is to use commercially available virus scans and security components, such as VPN Edge ports, which, however, increase the initial investment cost of the monitoring network compared to the first option but where meanwhile the life-cycle costs of the network would be less expensive. All in all, both the solutions are functional and increase significantly the security of the data transfered through the Internet.

5. CONCLUSIONS

The Internet Protocol Suite as an open standard is the most widely used set of communication protocols worldwide. The telecom industry is also continuously developing new technologies based on the TCP/IP protocol stack due to its global prevalence. To be able to take advantage of all the possibilities these new communication technologies introduce, to improve the quality of products and services, and to promote and facilitate international standardization and compatibility of meteorological observing systems the members within the WMO Global Observing System should consider moving gradually towards the surface weather observation networks supporting TCP/IP based solutions. This is at least what many other industries have already done.