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Future-oriented web server technology for field devices

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Introduction – Web technologies are changing the world

This white paper outlines how and why web servers are able to improve the integration and operation of field devices in process automation. The Internet and web technologies have fundamentally changed our modern world – and not just in terms of our day-to-day lives, which are distinguished by technology in the areas of communication, entertainment and spreading of knowledge. Many other new possibilities have emerged solely because of our networked world resulting in significant changes to the world of industrial production and automation, which have also reaped the benefits of these developments. Web server technology is one of these steps forward, opening up new paths for data exchange and communication. Today web servers have become ubiquitous as they are, for example, integrated into Wi-Fi routers, ATMs, TV set-top boxes and many other devices. Web servers provide easy access to devices for configuration or, in terms of remote maintenance, for retrieving measurement and diagnostic information.

The automation and process industry is faced with all kinds of challenges. Plant operators – to name just one example – are always looking for the simplest possible means of operating a specific system and its components in the most efficient way. In order to provide this level of time/cost optimization, special operating software along with required drivers (DTM/FDT and DD/EDD technology) are used to operate devices. This software is often specific to one manufacturer. The result is a complex update and version management of drivers and software, for both the manufacturer and the user. This is why Endress+Hauser seeks to minimize the time and money customers spend searching for and assigning drivers using new services such as its “Device Integration Manager.” However, acquiring these kinds of tools and drivers entails a significant amount of additional time and expense, employee training and infrastructure for the user.

Despite this extra effort, this architecture with its comprehensive network structures and plant asset management systems (PAM) provides advantages at every point – specifically for larger systems and operators with numerous field devices (actuators/sensors) from a vast assortment of manufacturers. Such PAM systems can provide scan functions, centralized DB functions, documentation functions and much more. By the same token, Web server technology enables significantly easier access to individual field devices in many applications, regardless of the size of the operations – such as for start-up or retrieving diagnostic data for process optimization. This is linked to a significant reduction in complexity for the user.

Despite this, complexity still remains, resulting from the tremendous increase in the number of different device types, protocols and tools for users, as networking and communication technologies have become increasingly more prevalent in the field in recent years. Endress+Hauser has now taken this development into account and has integrated web servers into its Proline flowmeters as a standard technology for the benefit of plant operators.

A win-win situation

The user's point of view: Standardized tools enable simple device operation
There are a variety of reasons why a web server integrated right into the measuring device makes life easier for users. In many devices – such as laptops, tablets and even smartphones – web browsers come pre-installed as part of a default software package, offering free access to web servers. This means there is no need to install anything, which not only saves time, but also reduces the potential of installation problems. Making software installation unnecessary in such cases also means there is no reason to make changes or apply updates to the operating system, as is normally the case when installing software.

Moreover, there are other important reasons that showcase the value of using this standardized technology, not least of which is that the user does not have to be so familiar with software, operating systems, and IT. Time pressure and cost pressure are currently generating demand for simple and time-saving operating concepts. Here again, well-established web technologies do not require any expert knowledge or even information technology specialists, making it possible for every user to operate field devices conveniently.

Furthermore, web browsers are easy to maintain, since generally no software or hardware incompatibilities are to be expected. This is because web browsers are generally independent from operating system versions and hardware requirements such as storage space and the like. As mentioned previously, version and update management for corresponding operating tools also becomes unnecessary. This relegates all-too-familiar problems such as "You need Version Y to operate Device X" or "The operating tool has Version Z; you need to download the newest Version A driver library" to the past.

One decisive advantage is that web servers usually work relatively easily with all web browsers, as long as certain rules are followed and the correct architecture is selected. This makes it easy to integrate them into various communication structures or Ethernet-based networks. It is precisely these integration features that play a central role in plant design, thus ensuring maximum efficiency and availability of process facilities. Equally promising is the hope that web browsers will provide the basis for innovative user interfaces such as touchscreens, 3D glasses or virtual-reality devices. In conclusion, it can be seen that web servers create a wide variety of advantages and possibilities for the user without limiting the range of functions and features of existing operating software.

The developer's point of view: Fewer restrictions, greater flexibility
In addition to the improvements from the user's perspective, web servers are an interface technology associated with many advantages and freedoms from the manufacturer's perspective, as well. Using web servers is a clever means of making all device functions available to users. This is because these functions are already contained in the device as a sort of firmware and do not have to be additionally mapped on a computer as operating software. If, for example, a flowmeter offers 15 operating languages, these are also available in the web browser, regardless of the operating device used. If certain functions or device properties change, a simple device update is sufficient; the driver and operating software are independent of this.

At their very core, web servers are designed to act in a client-server environment. This makes it possible to realize both data traffic and participation in networks with communication on various levels. They are useful as part of the integration and control of field devices.

Another point is the great flexibility resulting from the design of the graphical user interface, as web technologies are designed for comprehensive graphical and functional illustration options. This is largely due to the very lean protocols used for designing graphical user interfaces (GUI). The flexibility can be further increased if as many elements as possible are made modular, allowing them to be reused. For the user, this ultimately means better usability and lower investment.

One last important consideration – unlike the traditional approach of software or operating tool development – is the potential improvement in the software and the vastly easier life cycle management as a result of using web server-based technologies which in turn means higher efficiency for the device manufacturer.

Conclusion: Users can also benefit from these important, developer-oriented advantages. The following chapter describes the architecture of a flowmeter with an integrated web server and what needs to be taken into consideration to ensure the aforementioned advantages.

Architecture of embedded web servers

This chapter presents the implementation options for the various forms of web server architecture on a technical level to illustrate the various ways in which state-of-the-art IT and software methods can be used to implement the customer benefits in industrial applications.

Device integration
As mentioned previously, web servers enable simple integration of field devices and a corresponding connection to the embedded applications. This makes it possible to guarantee a link between the local application and a network (generally speaking the Internet). Moreover, HTTP-based applications also enable integration into the distributed applications available on the network. In this setup, HTTP can be

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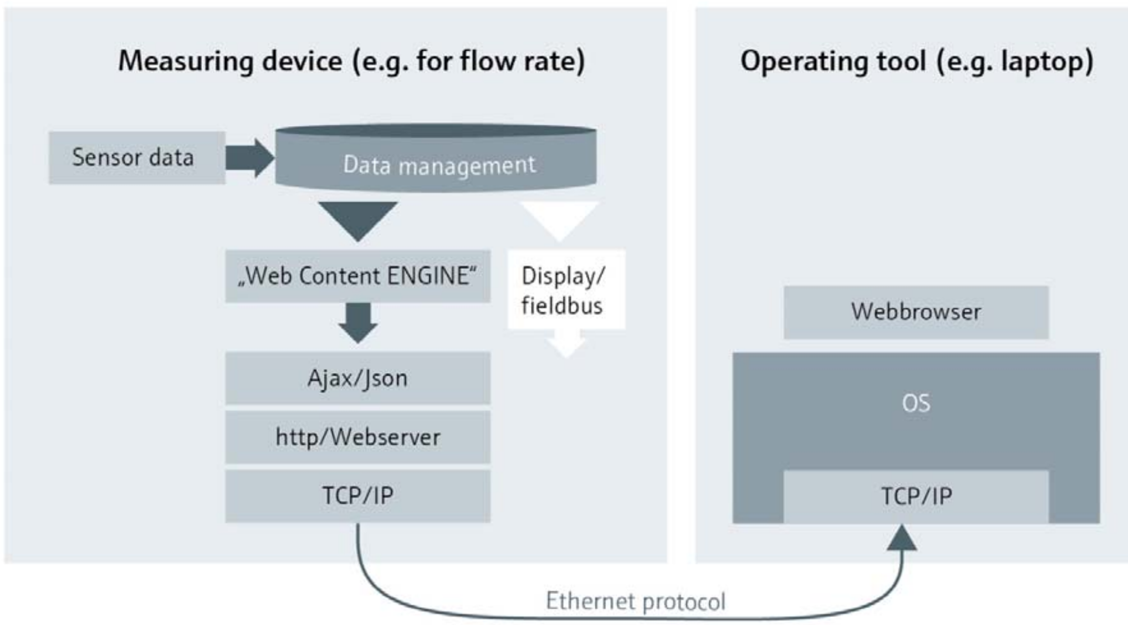
run directly on any device that has a web browser. This specifically eliminates the need to install additional software, regardless of the hardware or operating system platform.

The following figure shows an example of this kind of system, where measured values and device data processed on a device using a web server are shown in a web browser at a physically separate location.



In order to implement this approach, new components have been integrated alongside the traditional measuring chain where sensor data is processed for communication using analog or fieldbus signals. These new components prepare and communicate the data for the web browser application parallel to existing data channels. The contents this requires are generated automatically with the help of high-performance generators using standardized data models as a basis and can thus be integrated easily into existing software architecture.

The outlined web server communication encompasses the entire communication protocol stack, including from Layer 1 and 2 (with Ethernet) to Layer 3 and 4 (with TCP/IP) all the way to Layer 7 (application layer with HTTP and extensions). The following sections provide a brief overview of these elements, their function, and their features.

Ethernet
Over the last 30 years, the IEEE802.3 standard has emerged as the comprehensive solution for protocols in Layer 2, the data link layer (DLL), for local area networks (LAN) ever since its development by DEC, Intel and Xerox (DIX) in the 1980s. This has made a vast number of benefits possible: high data rates, simple operation, very high availability and low costs. Sensible compromises in the complexity of

the circuitry and the extremely high numbers involved in semi-conductor manufacturing are the primary factors responsible for these low costs.

Within this framework, Ethernet enables excellent interoperability and scalability. This is what enables, for example, old systems with a transmission rate of 10 Mbps over twisted pair cables (10Base-Tx) to communicate directly with high-performance, state-of-the-art 1 Gbps or even 10GBase-T systems. A series of plug-and-play services was defined and implemented right from the start to make this possible. These services include aspects such as Auto Negotiation Protocol (ANP) for negotiating the speed and duplex modes or Auto MDI-X, which can be used with all cable types (crossover or straight cables) for connecting stations without any other modifications or configurations.

Ethernet's basis in the IEEE802 standard also makes connecting to other protocols from this family simple and straightforward. Theoretically, future development could include wireless device networking, such as using IEEE802.11 (Wireless LAN) and a local control device for potentially hazardous areas. This would, however, require corresponding further development in hardware and software. Connecting Ethernet-based networks with common long-distance network traffic protocols (GPRS, UMTS, LTE) is not very complex either.

These factors make Ethernet a suitable network interface in almost every case where efficient engineering, cost-effective production, simple system integration, and automated start-up are in demand, rather than top-of-the-line performance. If the need for related wireless standards emerges in the process industry in the future, these kinds of devices could potentially be upgraded later based on web technology.

Transmission Control Protocol (TCP) and Internet Protocol (IP)

HTTP builds up the Internet Protocol (IP) and the Transport Control Protocol (TCP) based on the network level and the transport layer level (Layer 3 and 4 in the layer model). These two protocols are *the* key communication protocol bar none, both for the modern Internet and for directly connecting various devices. The devices themselves can vary wildly: TCP and IP make it possible to connect both small, cost-effective devices from industry automation as well as communication platforms from the sector of consumer electronics (smartphones and tablets) and expansive server farms for database systems at the backend all on equal ground. Both protocols are closely linked with each other and are frequently bundled together for implementation.

Internet Protocol in its two versions (IPv4 and IPv6) is used for connecting different networks (Inter Net Protocol). It enables addressing that is unambiguous both locally and globally, as well as converting between the two.

Auxiliary protocols help to provide simple and autonomous network management free of manual intervention. This primarily includes Dynamic Host Control Protocol (DHCP), which is usually used for the server-based distribution of local IP addresses and other configuration parameters, and the AutoIP protocol, which enables decentralized contact between local unambiguous addresses without a central unit. AutoIP can also be supplemented by the ZeroConf protocol (also known as the Bonjour protocol) to connect additional services automatically. These protocols are not used by Endress+Hauser devices at present for several reasons, one of them being security concerns.

TCP enables the setup of connection-oriented and reliable communication. Even if the use of very simple end-to-end receipt confirmations normally does not use a significant portion of the available bandwidth, the underlying TCP functionality is very easy to implement. From this standpoint, TCP is also capable of providing “robust” communication between any devices. In addition, it provides wide-ranging flexibility for expandability and scalability without limiting the fundamental interoperability.

HyperText Transfer Protocol (HTTP)

Web servers and web clients use HyperText Transfer Protocol (HTTP) on the application layer (Layer 7). Currently the two versions of HTTP, 1.1 and 1.2, are extremely widespread. Naturally, the fundamental functionality remains its ability to display HTML documents (HyperText Markup Language). With its basic function scope, HTML can be recognized, interpreted, and displayed in every web browser on any device. In this respect, it is very consistent in its pursuit of the “Any device” or “Write once, use everywhere” approach. The further development of this approach in the age of smartphones remains to be seen.

The client-server architecture in HTTP has the substantial and essential advantage that software to be run on the client can be provided on a server. This eliminates the need to install software on a client. In order to run the software, it can be loaded into a browser in a runtime environment instead. This also avoids problems related to software installation. In particular, these installation processes can be very annoying for the user, since they can be heavily restricted or even made impossible due to company-specific IT policies. This approach also makes it possible to store device-specific software in the device itself. This means the client no longer has to worry about different types and versions. As a result, life-cycle management in the field can also be simplified significantly.

If limitations are imposed to ensure basic and fully interoperable flexibility, compromises in graphical display and support for dynamic functions on the web page need to be taken into consideration. For example, a conventional static website has to be loaded or reloaded in its entirety every time. A few technologies have now been developed to counteract these limitations:

- JavaScript is an interpreted programming language that can be used both server-side and client-side for programming (scripts). JavaScript has largely been standardized as the ECMAScript language. It is frequently employed as client-side JavaScript in order to interact with the user, control the browser, communicate asynchronously (i.e. without a direct command from the user) and modify a displayed document dynamically.

  Using a standard JavaScript engine, advanced libraries can help with displaying complex graphics, providing sophisticated user interfaces and efficiently exchanging data with the server.

- Extended Markup Language (XML) has become the universal and generic approach behind reduced HTML. To facilitate this, XML enables the hierarchical display of data structures in an XML Document Object Model (DOM). Individual fields from the model can be retrieved using XMLHttpRequest (see: http://www.w3.org/TR/XMLHttpRequest/).

- Both approaches can be combined efficiently with additional benefits using Asynchronous JavaScript and XML in what is known as AJAX technology. With the help of the XMLHttpRequest command, JavaScript can also retrieve individual fields asynchronously (and in the background without user interaction as a result) and exchange data if the actual page has been loaded once before. This means the entire page does not always have to be reloaded. Of course, these updates can also be coupled with user commands.

  The data model is not limited to XML. Less intensive JavaScript Object Notation (JSON) can be used as well. It is standardized in RFC4627 and specifies a much smaller scope of formatting rules than XML (http://www.ietf.org/rfc/rfc4627.txt). It uses C-like structures, which is advantageous for its use in embedded systems. The combination of Asynchronous JavaScript and JSON is also sometimes referred to as AJAJ. This makes it possible to create very interactive websites both for devices with a human-machine interface and for machines that only communicate with each other (machine-to-machine communication or M2M communication) in order to reduce response times and volume of data.

In order to take advantage of these benefits, JavaScript has to be installed and enabled in the browser. In many companies, this is not the case for security reasons or only possible with a limited scope. This is also affected by the fact that browsers on smartphones have an assortment of special idiosyncrasies, meaning that fully developed AJAX cannot be used to its full extent. As a result, providing a dual solution where a static, HTML-based solution allows for complete, yet less convenient access is frequently useful.

Web Content Engine (WCE) and device integration
The effort required for developing and maintaining two parallel representations with the same function for the described http/AJAX/JSON architecture can easily be avoided if these two implementations can be generated automatically. That is precisely one of the tasks of what is called the Web Content Engine (WCE). One component contains the complete device description, including the function and configured parameters, which follow a uniform data model for products from Endress+Hauser. Measured values, among other things, can also be processed in this component. It is a data processing unit based on Ethernet communication and separate from the measuring system and fieldbus communication. Thus the WCE in the device generates all content displayed in the web browser application. However, this modeling is only possible if well-defined and prioritized interfaces are available. In the architecture shown, the WCE is responsible for collecting the data from the device and forwarding it to the device via Ethernet protocol to/from the web browser. In doing so, three foremost objectives are to be taken into account:

- So that measuring tasks which are to be performed **in real time** remain completely unaffected, the web server and the WCE in the real-time operating system (RTOS) are run with ~~a~~ low priority and deadlocks are prevented by strict resource management.
- To increase efficiency and prevent inconsistencies, all data has to be saved **centrally just once**.
- The transmission channel has to transmit the data via Ethernet protocol to/from the web browser **securely and reliably,** completely and without errors.

Additional requirements for industrial applications

If devices are connected to networks and particularly to the public Internet, the risk of attacks and tampering consequently increases. Therefore, devices in industry, which are critical for use or necessary for operations, must above all be secured in such a way that the resulting risk does not increase. In particular, functional safety and data security have to be guaranteed.

Functional safety

Functional safety guarantees that a device functions correctly, without errors and reliably under any ambient conditions. The requirements are described in various standards such as IEC 61508 or IEC 61511 and are generally known as SIL requirements. These requirements are taken into account accordingly when developing Endress+Hauser flowmeters with this SIL option. Thus, devices with integrated web servers and the SIL option also fulfill the necessary safety requirements.

Furthermore, for applications in an explosion-proof environment, such as frequently found in process industries, the energy flowing into the system must also be limited to prevent explosions. Of course, this is also guaranteed for all Endress+Hauser products that communicate with Ethernet and are delivered with Ex-approval.

Data security

Data security is an indispensable prerequisite for functional safety (no safety without security), but also a security objective in and of itself, to achieve the confidentiality, integrity and authenticity of data transmission. Data security in the web server can be guaranteed in the current implementation with the following measures:

- For devices without an industrial Ethernet interface, only a local point-to-point connection is supported, so that access from another network – such as from the Internet – is not possible.
- In addition, a mechanical switch is available to enable or disable write access to the device. This way the device can be practically completely protected from tampering.
- The web server can be disabled via common user interfaces. However, subsequent re-enabling requires operation at the device or access to the fieldbus network of the device.
- The device software also uses mechanisms that ensure protected access, such as the control of read/write access.

It goes without saying that there is a need for increased security requirements in usage scenarios such as remote maintenance or sending email, for example. This can be achieved by encryption with https or cryptography, both of which have to be just as secure as in the IT area. Thus, existing implementations are also being further developed in industrial automation – with its increasing security requirements – to guarantee the maximum possible level of security for operators. These implementations will be oriented towards international security standards that are relevant for automation industries; however, these standards are still in the works.

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An eye on the future

For Endress+Hauser Flowtec, the development of devices with integrated web servers (Ethernet and TCP/IPv4) is an important step, but only a first step. There are multiple reasons why it is important and necessary to implement this technology in the future:

- Successful integration of a comprehensive and user-friendly operating concept is proof of a device generation fit for the future with modular software architecture and suitable device description models.
- Web servers provide clear added value for measuring devices through the easy-to-use approach, which many plant operators have long required and which will become even more important in the future.
- Internet Protocol version 4 (IPv4) will retain its relevance in industrial networks for decades to come. Potential integration or tunneling, as it is called, through IPv6 in regional or global networks is state-of-the-art and has already been implemented on a broad basis.
- This approach is basically kept so general in order to enable easy adaptation to future customer requirements and technical developments.

Naturally there are more than enough visions of the future work environment. In the future, a decisive factor for production plants will be the networking of devices and systems in local and global networks – not least of all for monitoring and operating devices by remote access. This step will no doubt require integrating devices into customer networks for the purpose of network management, network stability, and certain forms of protection for reasons of network security.

Such expanded integration and communication models would then enable fuller integration into local systems or Internet-/Cloud-based plant asset management systems – either by the plant operator or by service providers such as Endress+Hauser. To do so, Endress+Hauser already provides a suitable platform with its W@M Life Cycle Management – a web-based asset management system. The networking options mentioned would open up a whole range of tools and services for plant operators, tools and services for which they currently need separate, additional systems, or which are still not even possible today. These are, for example, saving data, exchanging device information, accessing manufacturer documentation or web-based services.

In addition to service and asset management, extensive networking down to the production level is currently a main goal aimed at developing and implementing Industry 4.0 devices and systems. This concerns secure and protected networking via Internet. In this world of the “Internet of Things,” use of distributed Cloud services could significantly reduce plant costs and increase reliability. Then new services, web services or service models could provide real added value for completely networked devices and systems.

For the realization of such scenarios, however, component manufacturers and plant operators still have to work together to further develop the tools, processes and protocols required. Then it would even be possible to implement concepts that enable remote access as independent machine-to-machine (M2M) communication.

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Summary

As shown above, based on the technologies available today, it is very easy to equip even automation components such as flowmeters with promising web server technology. The integration of Ethernet-based communication and the use of standardized TCP/IP protocols allow for clever implementation in measuring device architecture. In addition to measuring technology and signal processing, this implementation provides a parallel communication channel with a web content engine. The standardized, widespread protocols such as http or JSON (JavaScript Object Notation) data formats assist in using the advantages of web browsers efficiently. This way it is possible to improve the system integration and operating options of automation components significantly, despite demanding industry requirements and operating conditions within process automation.

Even if a web server itself provides no additional function or no benefit from the perspective of the measuring device, the user can still derive crucial benefits from the following: time savings, cost reduction and simpler workflows for commissioning and maintenance. At the same time, these technologies ensure transparency for foreseeable or future trends and requirements in the world of automation. That is because the Internet is now being followed by the "Internet of Things," or the fourth industrial revolution. For this reason Endress+Hauser is making an effort today to take into account the requirements of tomorrow – fully in line with the motto: "Nothing is as constant as change."