Out of the Fog:

Use Case Scenarios

Industry	Smart Factories
Application	Process Manufacturing – Beverage Industry

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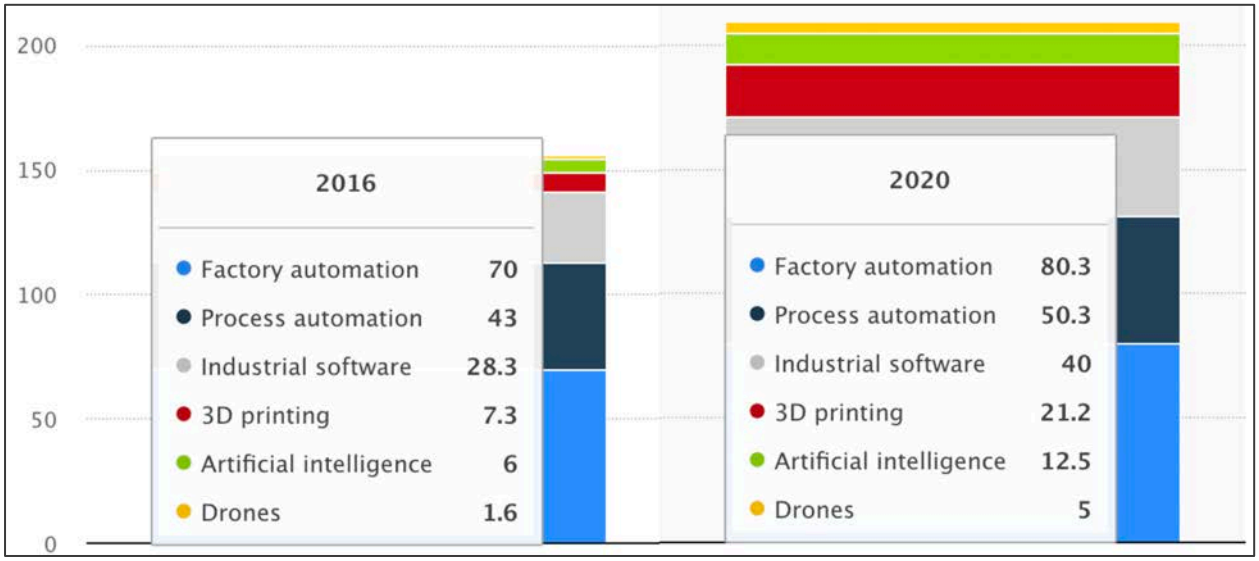
Executive Summary

Smart factories that utilize IoT and fog computing ensure a consistent supply and reliable quality for craft beer production:

- IoT technologies enable the techniques of crafters to be digitized and therefore reproduced with a consistent level of quality and uniformity. Large numbers of sensors and actuators throughout the brewery keep the production processes under tight control.
- IoT enables greater flexibility and adaptability in production processes, enabling a single factory to produce many more varieties of beer without massive changes to the production line, which can drive up costs.
- On the maintenance side, IoT sensors and applications can monitor and detect signs of product quality degradation in real time, facilitating a quick response.

Fog computing provides the foundation for the IoT-based smart factory. A fog-based infrastructure is capable of collecting the wealth of sensor data distributed among brewery equipment and aging vessels. In a fog environment, even the techniques used by experienced beer crafters can be digitally recorded and captured as data, to be repeated exactly in subsequent batches.

Global Automation Market Revenue for 2016-2018, Broken Down by Segment



The global market for process automation is expected to grow to around 50.3 billion U.S. dollars by 2020, driving spending in new technology spaces. (Statista, 2018. Figures express billions of dollars.)

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Challenges

- Maintain quality and consistency working with natural ingredients (whose behavior is idiosyncratic by nature).
- Reduce variances that can be introduced by manufacturing equipment/machinery and processes.
- Improve factory productivity /avoid work stoppage by discovering signs of mechanical problems before they affect production.
- Optimize factory investments for a growth business that is characterized by turbulent fluctuations in demand and high product mix.
- Minimize the impact of resource surpluses and shortages.

Solution

- The fog-based IoT smart factory reliably creates high-quality, highly-consistent products with minimal involvement from humans.
- By capturing the quality of products currently being made by manufacturing equipment/machinery in real time, and fine-tuning production parameter settings for the subsequent processes, the quality of products is improved in real time throughout the entire production process.
- A connection between manufacturing equipment and the systems of equipment manufacturers and maintenance providers allows signs of failure to be analyzed and the stock status of replacement parts to be checked. As a result, schedules can be adjusted quickly, and problematic parts can be replaced without interrupting the production process.
- The fog-enabled smart factory can efficiently integrate the supply chain, ordering ingredients and supplies just-in-time, and keeping distributors apprised of the progress of each production run.

Technology

- Fog nodes that capture and analyze actions of expert brewers to create digital twins.
- Autonomous systems that include intelligence from multiple fog nodes, involving sensors and actuators at all phases of production.
- Simple, flexible and secure interconnections between equipment and maintenance systems using fog nodes.
- Construction of autonomously-distributed resource pools using virtualization technology.

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The Challenge of Craft Beer Processing

Unlike industrial production that uses inorganic resources, the food and beverage industry has to deal with the products of nature. In the case of craft beer brewing, this involves ingredients such as malt, hops and brewer's yeast. Creating a uniform product is more difficult when you're working with organic material.

That challenge is magnified by the fact that brewing craft beer involves brewing many different varieties in small quantities. This makes it difficult to select optimum parameters for different varieties in a range of different conditions, and dynamically adjust for process variations.

Various elements, for example the temperature and moisture in upstream and maturing processes or the state of yeast and hops, must be adjusted alongside other elements such as ingredient quantities, proportions, process time and temperatures, maturation periods, and so on.

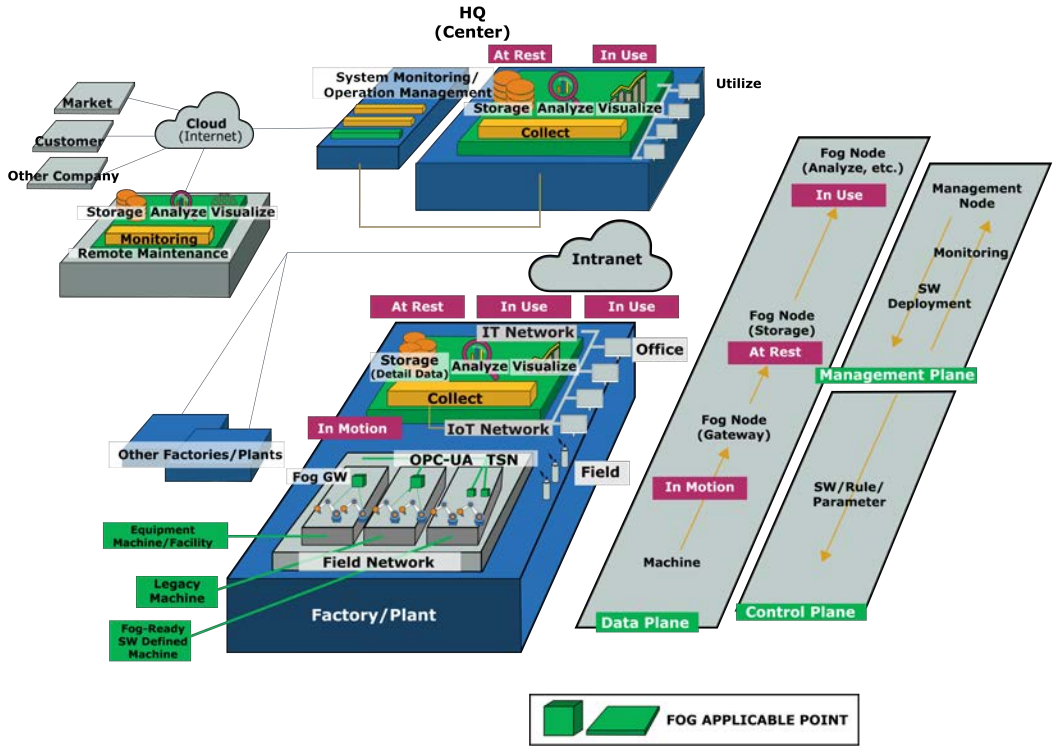

Figure. Fog computing across a smart factory spans production and business activities.

This delicate process depends on the ability to apply the experience of crafters to scale to higher volume production without sacrificing quality, to work with manufacturing partners to

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deal with fluctuating demand, and to make business and operational improvements. As a result, brewers cannot simply flip the switch to speed up production.

Incorporating advanced fog-based IoT technology into craft beer manufacturing plants creates smart factories that can accomplish the following:

- Reproduce the skills of a crafter through the creation of a "digital twin," using data collected from sensors on vessels and other production tools. (A digital twin is a digital replica of physical assets, processes and systems that provides both the elements and the dynamics of how an IoT device operates throughout its life cycle.)
- Create a stable inventory supply by securing materials based on demand forecasts, optimized inventory management, and coordination of the supply chain and production resources.
- Achieve real-time maintenance response based on automated, predictive detection of manufacturing equipment failures and inventory/order management of maintenance parts.
- Ensure quality monitoring and low-latency response to quality degradation, reducing losses caused by defective products.
- The local intelligence of fog computing supports smart manufacturing on the shop floor by enabling materials to be secured based on demand forecasts, optimized inventory management, and advanced detection of production equipment problems for preventive repairs.

Interoperability. In the fog-architected beer brewing scenario, interoperability plays an important role. Here are two examples:

1. Remote maintenance can be a key factor in improving yield rates and production efficiency. Remote equipment and systems using different protocols and data formats (including legacy production machines) can be connected easily, thanks to the interoperability enabled by OpenFog Reference Architecture.

2. To meet fluctuations in demand, beer brewers can dynamically create virtual groups of fog nodes across multiple fog networks. This enables multiple factories to share production equipment. Interoperability is required to create these virtual groups. Platform-level, modular interoperability enables legacy systems' resources and properties to be exposed as sharable smart objects to the information and device models in virtualized environments. This includes common interaction procedures.

Analytics. Fog is a key enabling factor in the software-defined smart factory. Factories have high levels of confidential information – beer recipes, production processes and failure logs, just to name a few. Further, many manufacturers want to store the data on their own premises, not in the cloud. In these cases, data analytics needs to take place on the device side without sending data to a remote cloud.

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Analytics on the fog node at the local site alleviates the increased demand of the bandwidth to the cloud. Analytics on fog nodes onsite also solve time constraint problems, because the round-trip time lag between production line sensors, to the cloud, and back to production line actuators isn't needed – and the local fog node can react and make decisions in real-time, or, in challenging cases, within tens of milliseconds.

Fog can orchestrate multiple business processes, such as beer brewing and logistics. The hierarchical structure of fog nodes forms dynamic groups to exchange the needed information for efficient collaboration. For example, a company can fill a temporary shortage of production capacity by tapping into another company's idle equipment.

Fog and IoT also help craft brewers solve the problem of replicating and automating the knowledge and techniques of their crafters. This is not only a productivity requirement, but it helps secure the techniques as company-owned intellectual property or proprietary assets.

An Architectural View

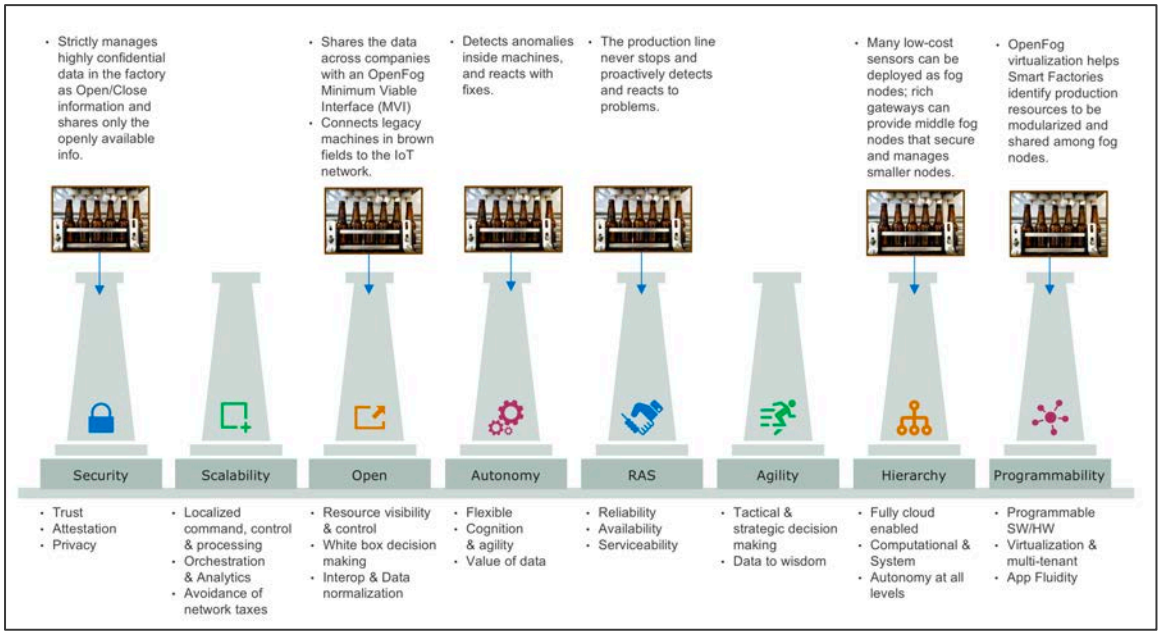

Figure. The OpenFog Reference Architecture pillars mapped to the process manufacturing use case.

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What is Fog Computing?

Fog computing is a system-level horizontal architecture that distributes resources and services of computing, storage, control and networking anywhere along the continuum from Cloud to Things.

- **Horizontal architecture:** Supports multiple industry verticals and application domains, delivering intelligence and services to users and business.
- **Cloud-to-Thing continuum of services:** Enables services and applications to be distributed closer to things, and anywhere along the continuum between Cloud and Things.
- **System-level:** Extends from the Things, over the network edges, through the Cloud, and across multiple protocol layers – not just radio systems, not just a specific protocol layer—not just at one part of an end-to-end system, but a system spanning between the Things and the Cloud.

Process manufacturing for the beverage industry is just one of many industry use cases whose commercial viability will depend on fog computing in order to achieve the rapid response, bandwidth and communication necessary in advanced digital applications. This case study was extracted from the detailed architectural overview paper located on the OpenFog website.

About the OpenFog Consortium

The OpenFog Consortium is a global nonprofit formed to accelerate the adoption of fog computing in order to solve the bandwidth, latency, communications and security challenges associated with IoT, 5G and artificial intelligence. Our work is centered around creating a framework for efficient and reliable networks and intelligent endpoints combined with identifiable, secure, and privacy-friendly information flows in the Cloud-to-Things continuum based on open standard technologies. For more information, please contact us at info@OpenFogConsortium.org.

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