SURF THE WAVES: A single pen built by Arctic Offshore Farming can hold 600,000 adult salmon. Fish are harvested from the bottom section of the two-tiered system.

stationed about 400 meters from the farm. One barge can monitor a cluster of fish farms and restock them with feed pellets every 7 to 14 days. With a volume of 120,000 cubic meters, each pen can hold up to 600,000 full-grown salmon at a time.

Standard feeding systems blow feed pellets through air hoses floating on the water's surface. But this approach doesn't work in the open ocean, where waves and winds would scatter the feed out to sea. Instead, the new feeding system automatically releases the feed underwater one to three times per day, allowing currents to distribute the pellets. Cameras allow crew members on the barge to see where the fish are located and release feed in those areas, reducing waste.

Although jobs in salmon fishing are about to get more technical, they don't have to be more complicated, says Lars Andersen, a sales specialist in aquaculture at ABB. The company built an interface for the salmon pen that displays the controls and safety systems in a simple dashboard.

As for the fish, their experience will more closely represent a life lived in the wild, says Hatlebrekke. Wild salmon that begin their journey in freshwater rivers spend only a few weeks in the sheltered fjord waters before they swim out to the open ocean. As farmed salmon operations incorporate more technology, the lives of farmed fish could mimic this path from freshwater to open sea, for a more natural existence.

—TRACY STAEDTER

A version of this article appears on our Tech Talk blog.

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HOW YOUTUBE LED TO GOOGLE'S CLOUD-GAMING SERVICE

The tech that made YouTube work everywhere promises to do the same for games

When Google's executives floated a vision for the Stadia cloud-gaming service, which could make graphically intensive gaming available on any device, they knew the company wouldn't have to build all the necessary technology from scratch. Instead, the tech giant planned to leverage its expertise in shaping Internet standards and installing infrastructure to support its YouTube video service for more than a billion people worldwide.

When Stadia debuts later this year, customers will be able to start gaming almost instantly by launching a simple client program that runs on Chromecasts, Chromebooks, PCs, and smartphones.

"Our vision is to have Stadia available on all devices that stream YouTube—a truly platform-agnostic service," says Majd Bakar, vice president of engineering for Stadia.

Cloud gaming has stricter technical requirements than streaming videos do. Video-streaming services such as YouTube and Netflix need to deliver video only when a person presses Play. For Stadia, a user's device must also perform additional processing to handle inputs from a player's controls.

Whereas live video streaming may have 500 milliseconds (half a second) to manage possible network glitches without noticeable interruptions, Stadia could have just 16 milliseconds or less to deliver a smooth experience for real-time interactive gaming.

Google harnessed technologies and infrastructure developed for YouTube—and engineered a few new ones—to prepare for Stadia's planned November 2019 launch in the United States, Canada, and a dozen European countries.

To use Stadia, Google recommends a minimum Internet download speed of 10 megabits per second to experience a game with 720p resolution at 60 frames per second. The service requires a minimum upload speed of 1.5 Mb/s.

Delivering high-intensity graphics over such limited bandwidth would not be possible without video codecs, which compress digital video files into smaller files. Compressed video files require less bandwidth and less time to transfer between a server and a person's device. That makes a huge difference for video streaming, which represents more than half of all downstream Internet traffic. YouTube alone makes up more than 10 percent.

Like YouTube, Stadia will lean heavily on video codecs to compress graphics into chunks of data that are easier to deliver. One called H.264 is a common compression standard for popular video-streaming services, Blu-ray discs, and HDTV broadcasts.

Google has developed a competitor called VP9 that delivers HD and 4K video streaming on YouTube with half the bandwidth of other codecs. The Stadia team has created "purpose-built custom hardware accelerators" that perform speedy encoding at scale based on both of those video codecs, Bakar says.

Another technology behind Stadia's cloud gaming is a variety of transport protocols—including basic pro-

tocols such as the Transmission Control Protocol (TCP)—that pass data between Internet-connected devices. One protocol used by Stadia, called WebRTC, arose from an open-source project supported by Google, Mozilla, and Opera. WebRTC allows software developers to build real-time video and audio communication into Web browsers such as Google Chrome and apps such as Google Hangouts and Duo.

Stadia will also rely on Google's QUIC (Quick UDP Internet Connections) protocol, which has reduced connection times and minimized delays in transmission in comparison with TCP. Google's Chrome browser and various apps already use QUIC for more efficient data transmission. But the protocol's capability to deliver data with less latency should also make a big difference for online gaming.

Another speed boost will come from Google's development of a congestion-control algorithm called BBR (Bottleneck Bandwidth and Round-trip propagation time). This algorithm can accurately measure Internet traffic and regulate how much data it puts into a network at any given time.

"Stadia's adaptive streaming technology adjusts to network quality in real time," Bakar says. "Alongside techniques like BBR, we are able to detect network impairments such as congestion prior to them happening."

These video codecs, Internet protocols, and congestion-control algorithms help Google make the best use of the existing bandwidth available in today's fiber-optic cables that connect data centers to customers. And like many tech giants, Google has invested in private Internet infrastructure so that it can more quickly deliver online services. In fact, Google has shared or complete ownership of approximately 8.5 percent of the world's submarine cables. And if there is a physical heart for Google's services, it's the company's 16 huge data centers, located in the Americas, Europe, and Asia.

Last but not least, Google has placed more than 7,500 edge nodes, which are Stadia servers installed in the networks of Internet service and network providers. Those edge nodes represent the Google infrastructure closest to customers.

Stadia will use a custom-built AMD GPU (graphics processing unit) that can deliver 10.7 teraflops of performance. That compares very favorably with the graphics cards in traditional video-game consoles such as the Xbox One X, with 6.0 teraflops, and the PlayStation 4 Pro's 4.2 teraflops—and Stadia could even leverage many graphics cards at once to supercharge gaming experiences.

Google's success in supplying YouTube and other Google services to billions of customers seems to have yielded useful lessons for the company's move into cloud gaming. "As long as these devices have good Internet connectivity and are able to decode high-quality video, they can handle Stadia," Bakar says. —JEREMY HSU

A version of this article appears in our Tech Talk blog.

REAL TIME: Google must reduce latency to 16 milliseconds for online gaming, compared with 500 ms of latency for streaming live video.

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GOOGLE

U.S. AIRLINE ORDERS FIRST PASSENGER ELECTRIC PLANE

The battery-powered nine-seater aircraft will enter service in 2022

Electric aviation took a big step forward in June when a Massachusetts-based airline announced it had placed the world's first order for a commercial all-electric passenger airplane. The Alice, a three-engine, battery-powered airplane that can fly up to 1,000 kilometers on a single charge, will be delivered to Cape Air in 2022.

The Alice, manufactured by the Israel-based startup Eviation Aircraft,