than those used for the decade-old HD Voice system, and it can squeeze stereo speech spanning the whole audible range into data rates as low as 9.6 kilobits per second. The codec also includes other algorithms developed to compress music.

The separate algorithms are vital because speech and music are compressed in different ways. Voice compression typically relies on algorithms called code-excited linear prediction (CELP), which is built on the physics underlying the human vocal system. CELP can reduce the data rate of voice signals by about a factor of 10. "That coding did a good job on speech but was terrible on everything else," says Richard Stern, an electrical and computer engineering professor at Carnegie Mellon University, in Pittsburgh.

Music-compression algorithms, such as the MP3 and AAC codecs used for streaming audio, are optimized for human auditory perception. For example, the algorithms don't bother to accurately reproduce the soft components of sounds likely to be masked by louder sounds at other frequencies and times. That method can represent a wider range of sound, but it requires more bits per second than a speech-based codec, Stern says.

The new EVS codec is a hybrid, containing algorithms for both voice and music, and it switches between them as needed. The new voice algorithms are substantially more complex than those of the decade-old 7,000-Hz codec. Rather than being developed around characteristics of specific languages, as earlier codecs were, these are nearly language independent. The music part is the latest low-latency version of the AAC algorithm, developed for real-time streamed communications. Called AAC-ELDv2, it delivers CD-quality stereo sound in a stream of only 32 kb/s by transmitting one stereo channel plus a lower-data-rate signal that represents the difference between that channel and the other stereo channel.

An important feature of the combined package, says Baumeister, is that EVS is the first codec designed to compensate for packet loss. Such losses degrade voice quality and are inevitable on IP networks such as 4G LTE.

To verify performance of the codec and its loss tolerance, Fraunhofer IIS and 11 partners—including Ericsson, Huawei, Qualcomm, and Samsung—spent millions of euros on human listening tests. Full-HD Voice quality was possible even at data rates as low as 9.6 kb/s.

The processing power of modern smartphone chips is a key enabler for the new codecs. They can be implemented in digital signal processing chips as the 7,000-Hz codecs in 4G smartphones are, or as apps running on a smartphone's applications processor. The EVS codec "is not complex compared to the apps in a smartphone," says Baumeister.

Because Full-HD Voice can tolerate packet losses, it could feed compressed data directly into the Internet data stream for routing directly to other equipped devices, like a Skype-to-Skype call between computers or smartphones. Fraunhofer's Mobile World demonstration did that using apps on Google Nexus 5 phones. With no need for network upgrades, Baumeister says, "you could conceptually roll out service this year, but next year is more realistic."

You can hear samples at http://www.full-hd-voice.com, but be sure to use good headphones in a quiet environment. Stern compares the difference to the shift from standard resolution to HD television. "It's going to be subtle, not a huge difference in intelligibility, but it will sound better and more natural, like a high-quality speaker system," he says.

—JEFF HECHT

SMART SEWERS FOR PUBLIC HEALTH

With robotic samplers, public-health officials will study cities' microbiomes

Newsha Ghaeli reached down an open manhole one morning in April and grabbed a hose dangling in the rushing streams of the sewer below. As she pulled up the hose, she spotted a wad of toilet paper clinging to its end and recoiled in disgust, accidentally splashing a few drops of dirty water on strands of exposed hair sticking out from her face mask. A Cambridge, Mass., sanitation worker offered comfort: "A little caca won't hurt you," he said.

Ghaeli is an architect and research fellow at MIT who recently helped coordinate a 24-hour effort to collect water samples from the sewer beneath an East Cambridge neighborhood. Every hour, the team pulled up half a liter of precious sludge. Ghaeli and her colleagues were doing the groundwork for an ambitious project that aims to understand the well-being of a city by tracking its residents' biological and chemical waste. Eventually, with robotic samplers placed below the streets, Cambridge may have a "smart sewer" that will let public-health officials study the city's collective microbiome—the communities of microorganisms that live in humans' guts.

"The idea is to look at patterns of sewage relative to how we live our daily lives," says Yaniv Jacob Turgeman, who until recently was the research director of the project. "We want this to be something that has actionable insights that enable public health in a meaningful way."

The project—dubbed Underworlds and supported by a US $4 million grant through the Kuwait-MIT Center for Natural Resources and the Environment—is one of a few with that goal, and it has been embraced by the city that the research team calls home. "If you get information closer to real time, you can rally resources to try to address a problem before it becomes a much bigger problem," says Sam Lipson, director of environmental health for Cambridge. "Those kinds of metrics are generally not available in public health."

Until recently, this type of "sewage epidemiology" was used mostly to monitor population-level trends in illicit drug use. In Europe, for example, a recent study of sewage from 42 cities throughout the continent revealed that cocaine and ecstasy use was greatest in large metropolises on weekends, whereas cannabis and methamphetamine use was

THE QUANTIFIED SEWER: Scientists sample sewage in Cambridge, Mass., to prepare for a large experiment that will seek to track the city's health by examining its waste.

ELIE DOLGIN

more evenly distributed throughout the week in towns of all sizes.

The MIT team will also test for drugs—both illicit and pharmaceutical—but it plans to go much further, albeit in a research capacity. (Lipson stresses that a community review process would need to be completed before any comprehensive monitoring program commences in Cambridge.) Led by Eric Alm, a computational microbiologist, and Carlo Ratti, an architect and engineer, the Underworlders will screen for viruses, such as influenza and norovirus, to detect incipient outbreaks in Cambridge. They will sequence the DNA of bacteria to identify food-borne pathogens. And they will search for biochemical indicators of various aspects of human health and disease.

"The MIT project is extremely ambitious and pioneering," says Christian Daughton, a chemist with the U.S. Environmental Protection Agency who spearheaded the idea of using sewage to track community health. "If this project proves successful in demonstrating some sort of proof of principle, it could represent a significant, seminal advancement in the prospects for quickly and inexpensively monitoring public health in real time."

That next level will be far more automated. Ratti and his team at the MIT SENSEable City Laboratory are currently designing manhole-width, 30-centimeter-tall robots that will be suspended on cables to allow them to move up and down vertically in the sewer. Using a custom-made smartphone app and a Bluetooth connection, the researchers will be able to control the robots remotely to collect samples and feed data into a detailed sewage sampling information system. The robots will serve mostly as collection vehicles, although the researchers hope to embed sensors to measure temperature, flow, and other parameters.

The plan is to start testing the robots in the sewers in the coming months as the researchers ramp up to 10 sites throughout Cambridge. In this way, they hope to gain a sense of the geographic diversity of sewage signals across the city. Later this year, they will also begin to set up a similar platform in Kuwait, a country that's almost 1,000 times the size of Cambridge. "The scale of what they're trying to do is impressive," says Ryan Newton, a microbial ecologist at the University of Wisconsin-Milwaukee who has worked with wastewater samples. "They should be able to get a really, really good handle on the variability in that population."

More than one-third of Kuwaiti children are overweight or obese. With enough long-term data from Kuwait, sewage analysis could theoretically reveal whether public health campaigns, such as a recent effort to curb the amount of sodium in bread, are having an impact on people's metabolic well-being.

Similar efforts are gearing up around the world. New York University biologist Jane Carlton will report at the Microbes in the City meeting this month that she and her colleagues are halfway through a two-year project to characterize bacteria and other single-celled organisms as well as viruses living in raw sewage flowing though New York City. Carlton is also in discussions about establishing a comparable sewer sampling initiative in Shanghai.

Meanwhile, a team from the Argonne National Laboratory, in Illinois, has begun a seven-year project to test for metabolites and microbial life from the sewer overflow pipes and rivers of Chicago. As in the Underworlds project, much of the data collection remains manual for now. But Jack Gilbert, a microbial ecologist who is leading the Chicago initiative, is working on a battery-powered sensor that runs DNA amplification reactions to search for any of 385 different organisms in a single sample of wastewater. The microfluidic device is currently housed in a box about the size of a suitcase and transmits data via Bluetooth.

"We hope to have these sensors in-line from the sewage water treatment plants," says Gilbert. "The technology is still in a prototype form, but theoretically the microbiome and virulence factors associated with any potential threats could be automatically detected and relayed to a central system."

The possibilities are near endless, says Underworlds' Alm. The challenge is to determine what's feasible. "There are so many things you can do with the platform," he says. "Let's build it and then see what works." —ELIE DOLGIN