News and Perspectives

The Next Generation of Wearables Won't Need the Cloud

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Abstract

Wearable health and fitness devices have typically relied on cloud computing to deliver insights. In this *News and Perspectives* article, JMIR Correspondent Michelle Falci reports on the advances facilitating on-device data processing and the potential of these next generation wearables.

Key Takeaways:

- Wearable devices that process data locally have several advantages over devices that rely on cloud computation, including reduced latency and enhanced privacy.
- Advances in stretchable electronics that can conform to the body make edge AI–enabled wearable devices possible.

Historically, wearable devices functioned by sending data collected from the body to the cloud for analysis, then sending information back to the user. While cloud-connected devices can be an effective digital health tool, these devices have significant limitations, including security concerns.

"If you have to always put private and precious health data to the cloud, then that creates the risk of data being hacked or [the data] being used for other purposes," says Sihong Wang, PhD, Associate Professor of Molecular Engineering in the UChicago Pritzker School of Molecular Engineering.

Wang is one of many researchers working to realize a new generation of wearable devices that analyze and interpret data directly on the device, eliminating reliance on remote servers.

This shift is part of a broader trend toward edge computing, where data is processed where it is generated rather than in centralized data centers. For wearable health and fitness devices, this is possible thanks to advances in flexible electronics that function as skin-like systems capable of performing machine learning tasks on site.

"Miniaturized AI processors, energy-efficient system-on-chip architectures, and innovations in sensor technology—including flexible and stretchable electronics—have collectively transformed wearables into sophisticated computing nodes," says Pierluigi Gardella, Director of Healthcare Solutions at NXP Semiconductors.

A New Computing Paradigm

Wearable devices are more efficient data collectors when they have more skin contact, Wang explains. For devices that perform edge computation, researchers needed to find a way to develop a flexible system that can conform to the body and collect data and process it.

"We have been working on using a new computing paradigm called neuromorphic computing," Wang says. "[Which involves mimicking] how the brain works, how the neurons in the brain work at a hardware level to make the computing much more efficient, and can be realized with a smaller number of devices. Then, that also gives the possibility of designing it into a skin-like stretchable mechanical form factor."

Because of their reduced hardware requirements and increased energy efficiency, neuromorphic systems are a promising alternative to traditional wearables. Building on previous work that showed it was theoretically possible to build a stretchable neuromorphic computing circuit, Wang and his colleagues demonstrated the feasibility of this approach in their latest study.

"We have further developed the large-scale fabrication methods so that we can produce not only one device, but a large number of devices in an array, and then turn the array into a circuit," he says.

Applications for the Next Generation of Wearables

Bypassing the cloud with edge computing has three main benefits according to Wang: local processing saves time, it saves energy, and it is more secure than sending data to the cloud for analysis.

The flexible neuromorphic circuits developed by Wang and his team were used to demonstrate the feasibility of monitoring patients with ventricular fibrillation, a condition where seconds count.

"Especially if it's a rapidly evolving disease, and particularly if it's becoming life-threatening, each second could mean the chance of saving [a] life," Wang says. "Also, the disease or the condition could propagate very quickly. So then that could even make it impossible to analyze if there is a delay on the transmission of the data and the computing at the cloud's location. But with on-site computing, you can minimize the time cost in the double-way transmission of data."

Hearing aids are another example of how edge AI can reduce latency and improve user experience, according to Gardella. Research shows that AI-integrated hearing aids can improve speech understanding, and edge AI offers additional benefits.

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>
> Pierluigi Gardella

“The edge AI capability allows manufacturers to implement real-time AI algorithms for noise reduction or digital beamforming. If those same algorithms ran in the cloud instead, users could experience a latency or delay that compromises their quality of perception,” Gardella says.

In cancer care, edge AI–enabled devices can provide real-time monitoring at home, and emerging results show that these devices may reduce emergency department visits for patients with solid tumors.

Gardella predicts that edge AI-enabled wearables will serve as “the first line of defense” in some situations, such as monitoring hypertension or stroke risk.

“The shift from episodic measurement to continuous monitoring represents a fundamental change in how healthcare is delivered: moving from reactive treatment to proactive prevention,” he says.

What’s Next for Edge AI in Wearable Technology

Wang and his team are working to hone the batch-to-batch consistency of the devices to support manufacturing flexible neuromorphic circuits on a large scale.

“We want the fabrication to realize even smaller device size, and also to support the more sophisticated functions through having all the devices within a circuit to have more uniform performance,” he says.

The rigid complementary metal oxide semiconductor (CMOS)–based computing circuits required for machine learning pose another challenge. Evidence shows that taking an island-bridge approach, where rigid CMOS “islands” are linked with flexible connections serving as “bridges,” allows devices to bend and stretch without damaging their computing elements. However, this enables a hybrid system rather than truly stretchable, fully integrated CMOS-based computing.

Development efforts for turning conventional transistors into a stretchable form are underway, Wang says.

A future with access to devices that leverage flexible architecture and edge computation offers benefits to both individual users and health systems, according to Gardella.

“By bringing intelligence closer to the user, wearables are becoming more responsive, secure, and effective,” he says. “As technology continues to advance, edge AI will not only enhance device performance but also unlock a new generation of preventive, personalized healthcare experiences.”

Though challenges remain, offloading tasks from the cloud and using local processing reduces centralized infrastructure demand and costs associated with cloud computing. The time and energy savings enabled by edge computing, along with enhanced privacy, is promising for patients and health care professionals who increasingly rely on wearable devices to track vital signs.

Keywords: Edge AI; wearable technology; wearable devices; cloud computing; edge computing; CMOS; complementary metal oxide semiconductor

Please cite as:
Falci M
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J Med Internet Res 2026;28:e107247
URL: https://www.jmir.org/2026/1/e107247
doi: 10.2196/107247