Journal of Diabetes Science and Technology
2017, Vol. 11(4) 647–652

Reprints and permissions:
sagepub.com/journalsPermissions.nav
DOI: 10.1177/1932296817717007
journals.sagepub.com/home/dst
SAGE

Fog Computing and Edge Computing Architectures for Processing Data From Diabetes Devices Connected to the Medical Internet of Things

David C. Klonoff, MD, FACP, FRCP (Edin), Fellow AIMBE[1]

Abstract

The Internet of Things (IoT) is generating an immense volume of data. With cloud computing, medical sensor and actuator data can be stored and analyzed remotely by distributed servers. The results can then be delivered via the Internet. The number of devices in IoT includes such wireless diabetes devices as blood glucose monitors, continuous glucose monitors, insulin pens, insulin pumps, and closed-loop systems. The cloud model for data storage and analysis is increasingly unable to process the data avalanche, and processing is being pushed out to the edge of the network closer to where the data-generating devices are. Fog computing and edge computing are two architectures for data handling that can offload data from the cloud, process it nearby the patient, and transmit information machine-to-machine or machine-to-human in milliseconds or seconds. Sensor data can be processed near the sensing and actuating devices with fog computing (with local nodes) and with edge computing (within the sensing devices). Compared to cloud computing, fog computing and edge computing offer five advantages: (1) greater data transmission speed, (2) less dependence on limited bandwidths, (3) greater privacy and security, (4) greater control over data generated in foreign countries where laws may limit use or permit unwanted governmental access, and (5) lower costs because more sensor-derived data are used locally and less data are transmitted remotely. Connected diabetes devices almost all use fog computing or edge computing because diabetes patients require a very rapid response to sensor input and cannot tolerate delays for cloud computing.

Keywords

actuators, cloud computing, edge computing, fog computing, Internet of Things, IoT, sensors, wireless

Cloud computing is the practice of using a network of remote servers on the Internet to store and process data, rather than a local server or a personal computer. This term was coined by Compaq Computer in 1996.[1] Internet of Things (IoT) is a concept of devices being embedded with network connectivity that enable these objects to collect and exchange data without human intervention.

Cisco Systems has estimated that in 2020 all of the people and things connected to the Internet will generate 600 zettabytes (1 zettabyte = 1 trillion gigabytes) of data.[2] Today's cloud models are not designed for the volume, variety, and velocity of data that the IoT generates.[3] Soon cloud computing for medical devices will not be able to keep up with the data volume and costs generated by IoT devices. Cloud computing will also be unable to provide adequately rapid data transfer in specific situations, such as intensive care and emergency medicine, as well as autonomous closed-loop systems maintaining physiologic homeostasis. Cloud computing systems will become increasingly strained and networks will increasingly decentralize selected computing processes to be located at or nearby the medical IoT sensors, which are collecting the data.[4] The network architectures of the future or handling the convergence of the cloud-based Internet, mobile computing, and IOT data will be fog computing and edge computing.[5] Cloud computing is preferred over fog computing when complex analyses of the data are needed and when security maintenance for a single data repository (compared to multiple distributed repositories) is preferred.[6]

Fog computing and edge computing are new paradigms for data analysis and storage that add an additional layer of computing power between the cloud and a device, such as a

[1]Diabetes Research Institute; Mills-Peninsula Medical Center, San Mateo, CA, USA

Corresponding Author:
David C. Klonoff, MD, FACP, FRCP (Edin), Fellow AIMBE, Diabetes Research Institute, Mills-Peninsula Medical Center, 100 S San Mateo Dr, Rm 5147, San Mateo, CA 94401, USA.
Email: dklonoff@diabetestechnology.org

medical sensor or effector. The added layer is in close proximity to the data source. These architectures reduce the amount of data that must be sent to and received from remote servers on the cloud and facilitate immediate use of data that must be acted on within milliseconds of collection.[7] Fog computing may be useful for new paradigms in medical data analysis and remote health monitoring, such as analysis of big data, privacy aware distributed learning, and citizen science projects, to the extent that specific projects require immediate analysis of data.

What Are Fog Computing and Edge Computing?

The term fog computing was coined by Cisco Systems in 2014.[8] The term fog computing was used because fog is a cloud that is close to the ground. Fog computing for medical devices concentrates processing "down to earth" near the patient or where the sensor is collecting data rather than almost entirely up in the cloud.

The term edge computing has been used since around 2002.[9] An edge medical device collects data and also provides an entry point into a network or the Internet. The edge computing paradigm shifts control of a network's services away from central nodes (defined as the core) to the other extreme, which is the sensor itself (defined as the edge) rather than to servers or nodes. Edge computing has also been referred to as dew computing.[10]

The difference between the two architectures is the locus of where the additional computing power is located.[11] Fog computing assigns computing power down to the level of a local area network (which is a set of interconnected computers within a limited area) where data are processed within a hub, node, router, or gateway and then transmitted to the appropriate devices. A smartphone can serve in this capacity.[12] Edge computing, however, assigns processing power and communication capabilities of a data-gathering device directly into the device itself, which can be a sensor, a detector, an embedded system, or a smart object, and in some cases data are sent to a nearby a server. Fog computing generally uses open standard technologies whereas edge computing may use open or proprietary technologies.[13] Although there is overlap between the two architectures, in this article a system with a proprietary computing node at the edge of the network node is defined as using edge computing.

A fog computing node or an edge computing device, which combine sensing with the type of computing that is performed in a fog computing node, can each become a miniature analytics center for a local device or set of local devices and can perform many narrowly defined processes including exchange of data within milliseconds and thinning out data for long-term storage on the cloud or else short term storage in a fog hub or edge device.[14] Many medical actuator devices need to respond immediately to sensor data in milliseconds and cannot wait minutes for sensor data to be sent around the world, analyzed in the cloud, and then sent back.[3] Fog computing and edge computing are useful when the goal is instantaneous analysis of data followed by instantaneous generation of a rules-based command. These two architectures can allow medical sensor data can be put to use immediately, which will result in improved outcomes.

Edge computing could potentially be preferable to fog computing in that it contains fewer potential failure points. Each sensor or medical device in the network would be independently programmed and would determine what type of information should be stored locally and what would need to be sent to the cloud for further use.[15]

How Do Fog Computing and Edge Computing Differ From Cloud Computing?

Compared to cloud computing, fog computing and edge computing offer five advantages. First, even with their massive computing power for advanced analytics, cloud servers are often far away and slow to respond, whereas local processors can deliver information within milliseconds or seconds.[16] Data transmission from a sensor to a cloud server is typically multiple hops whereas sensors clients usually connect to fog nodes through a single hop.[13] Cloud computing, unlike fog computing, is subject to jitter, which is defined as a variation in the delay of received packets.[13] Some data are most useful immediately after they are collected, but days or even minutes later, they may be less useful, and uploading all data to the cloud for analysis can degrade some of their value.[17] Second, local computing devices (both fog hubs and medical edge devices) can function in places where significant bandwidth or reliable broadband Internet are not always available or where long transmission paths can interfere with reliability. Third, health care data that are collected and analyzed within a local network in proximity to a patient are more likely to remain private and secure than when they are uploaded to a remote server. Fourth, for data collected in foreign countries, cloud storage and data analysis may be limited in some countries by legal regulations[18] or subject to access by foreign governments according to local laws.[19] Fifth, local computing is less costly than remote computing because transmission costs generally exceed computation costs.[4]

Fog and edge computing can overlap in their functions and both can coexist within a single network of devices. In a fog computing paradigm, a device can transmit critical data to a nearby fog node for immediate analysis and response back to the device within milliseconds or seconds. A device can also transmit other data that can wait for a few minutes to a larger aggregation fog node that manages several IoT devices, and will pass the rest of the data (such as some medical billing data, lab results data, and appointment data) up to the cloud for long-term storage and analysis at a later date.[3] Data from the fog node or the fog aggregation node can be sent to the cloud for storage and analysis.[20] In an edge computing paradigm, devices can perform specific computations and communicate with each other. They can also transmit data to a node (known as a mobile edge computing server) for selected aggregation and responses, and from there the data are transmitted to the cloud.[21] Determination of which tasks go to a local fog or edge node and which go to the cloud depends on the application.

Three potential barriers to distributed data processing performed by fog or edge computing devices, which might be limited in computational power, include: (1) formatting medical data from various sources to a common architecture and also preserving privacy if data are to be shared; (2) balancing greater data abstraction to facilitate limited local storage against lesser abstraction to facilitate productivity; and (3) identifying unreliable data from isolated defective sensors or wireless transmitters.[22]

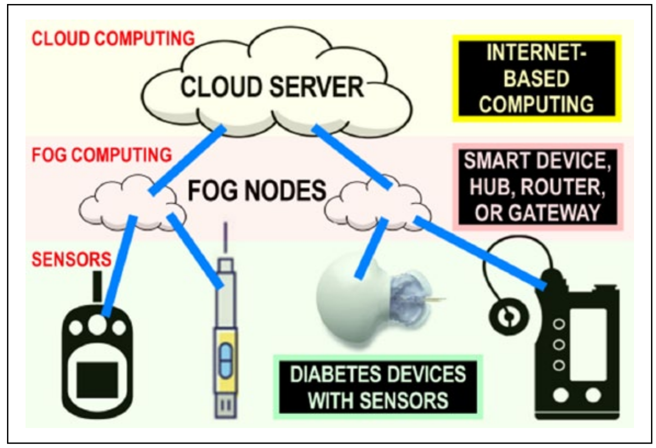

Figure 1. Hierarchy of sensors, fog computing, and cloud computing for wireless diabetes devices. This figure shows (1) diabetes devices with sensors, which include a blood glucose monitor, smart insulin pen, continuous glucose monitor, and insulin pump—and these last two devices operating together can constitute a closed-loop or artificial pancreas system (green background); (2) fog computing nodes, which include smart devices, hubs, routers, and gateways (pink background); and (3) cloud servers, which use Internet-based computing (yellow background).

Diabetes Devices Currently Using Fog Computing

The definition of a diabetes sensor in this article is a device that responds to physiological signals in a patient with diabetes and transmits resulting impulses with or without a display feature. The definition of diabetes data in this article is a set of converted physiological measurements with related contextual information (including time and date), rather than raw sensor data (such as current, voltage, resistance, and optical power). By this definition conversion of raw sensor data to a physiological parameter, would not automatically constitute an edge computation. For example, in the case of blood glucose monitoring, the conversion of raw sensor currents to BG values would not be considered to be an edge computation. Unless some sensor signal conditioning and calibration is allowed, then almost every diabetes sensing device will be defined as using edge computing even if the converted data are transmitted to an open source fog computing node.

Increasingly, wearable and portable diabetes devices are offering Bluetooth communication into a smartphone or tablet which serves as a portable fog computing hub by performing some basic analytic processes and also sending the monitored information to the cloud.[23] Few medical devices at this time transmit data directly to the cloud. Wireless portable diabetes devices can transmit data to the cloud by way of a fog computing node, such as a portable smart device (like a smartphone) or a desktop hub, router, or gateway system. These devices include blood glucose monitors, insulin pens, continuous glucose monitors, insulin pumps, and closed-loop artificial pancreas systems (which are comprised of a continuous glucose monitor and an insulin pump working together) (see Figure 1). Other wireless monitors that can be used by diabetes patients include blood pressure cuffs, weight scales, oximeters, ECGs, temperature monitors, and even wearable tracker devices with global positioning system capabilities.[24] The disadvantage of fog computing with these types of medical monitors is that the patient cannot upload data for real-time analytics if their smartphone or hub device is broken or not charged.

Some older blood glucose monitors do not upload data automatically and require a cable to connect with a hub device or a computer. These systems are not true fog computing devices but rather asynchronous telemedicine systems and they will not report analyzed patterns requiring a response until a patient or health care professional performs the uploading process. Over the past few years, such products have been replaced for the most part by monitors with wireless communication capabilities. An uploading process using a cable connection would typically not occur until a patient is scheduled to see their physician, at which point the patient would probably not have seen their data analyzed on the cloud and would probably not have received maximum benefit from the analytical capability of a device that can transmit data to the cloud for rapid analysis. Because of the risks of delayed notification, over the past decade the trend in medical device development is overwhelmingly away from asynchronous telemedicine[25] and toward fog computing to automatically upload data in real time.[26]

In the United States continuous glucose monitoring data can be delivered to a patient in real time with a personal system or retrospectively with a professional system. The two marketed personal system sensors, which are approved by the FDA, include Dexcom G5 Platinum (Dexcom, San Diego, CA) and Medtronic Enlite (Medtronic, Dublin, Ireland). These systems transmit through fog computing protocols to a smartphone or monitor and from there to the cloud. The professional versions of these two products also transmit via fog computing protocols. The Abbott Libre Flash (Abbott Diabetes Care, Alameda, CA) is approved only for retrospective review, and this product uses either a Bluetooth transmitter to connect with a reader that functions as a hub and transmits to the cloud where a detailed portrayal of continuous glucose readings can be studied. Several new BG Monitors transmit to a smartphone, hub, reader, but none directly to the cloud.

Optimal patient management requiring computation by virtually any diabetes sensor potentially requires an automatic response which might have to be immediate in many cases. Although some slowly changing medical sensor data do not require immediate analysis and can wait for minutes or even days for analysis, that is not the case for diabetes data, which are best used in real time. Most diabetes devices need to provide information whenever the patient with diabetes or the health care professional needs measurements, and not just when the patient has Internet access to data stored and analyzed in the cloud. Therefore, connected diabetes devices almost all use either fog computing or edge computing or a combination of the two architectures. Glucose values and insulin doses can require an immediate response and therefore require automatic analysis and uploading into the cloud with fog computing or edge computing processes.[27] Sensor-integrated pump systems, like the 530G and 630G by Medtronic Diabetes and closed loop artifical pancreas systems like the 670G by Medtronic Diabetes contain a continuous glucose monitor that is reporting discrete glucose levels to an insulin infusion pump every five minutes, but glucose sensor information is measured continuously. The glucose information along with additional types of information from accelerometers, and other sensors can be combined to deliver a recommended insulin infusion rate that can change almost continuously in response to changes in the metabolic milieu.[28] In such a system, it is necessary for decisions to be made locally with a processor located either worn by or carried by the patient (or somehow in the vicinity of the patient at all times) rather than by a cloud-based server which is going to suffer from potential delays in processing or temporary data dropout in case of data transmission problems.[29] Artificial pancreas systems in use and under development all use fog or edge computing systems.

Other Medical Devices Currently Using Edge Computing

Edge computing is currently used in several other medical closed-loop systems besides diabetes systems, where the sensor input is designed to affect the actuator output, including (1) cardiac pacemakers; (2) cardiac defibrillators; (3) investigational closed-loop mechanical ventilation systems[30] which are not yet on the market; (4) the Sedasys closed-loop anesthesia delivery system that was approved by FDA but taken off the market because of poor sales;[31] and (5) brain function which can be modulated with closed-loop stimulation.[32] Edge computing is suited for closed-loop systems that use smart sensors to maintain physiologic homeostasis, but the approach is adopted only to a limited extent currently because few autonomous closed-loop systems have been developed and approved by the FDA.[33] This approach would be suitable for an intensive care unit or an emergency medical department where acutely ill patients can require immediate responses to changes in their condition. Edge computing is achieved by connecting a system's sensors to small, local control systems that handle processing, and communication. The result of edge computing can be rapid machine-to-machine communication or machine-to-human interaction. This paradigm (compared to fog computing) takes localized processing farther away from the network right down to the sensor by pushing the computing processes even closer to the data sources.[34] The sensor can then either send information directly to another edge device, up to a fog node, or to the cloud. By using edge computing, instead of doing the bulk of processing in a centralized server or a distributed local server, each device on the network would play its own role in processing the information.

Future Trends in Managing Data Generated by the Medical IoT

By 2019, 45% of IoT-created data are expected to be stored, processed, analyzed, and acted on close to, or at the Edge of, the network.[35] The OpenFog Consortium was founded in November 2015 by representatives from ARM, Cisco, Dell, Intel, Microsoft, and Princeton University.[36] Its goal is to develop an interoperable fog computing architecture with sufficient latency, bandwidth, and security to support intelligence at the edge of the IoT, including autonomous and self-aware machines, things, devices, and smart objects. The organization now has over 50 member organizations.[37] The Edge Consortium was founded in November 2016 by representatives Huawei Technologies Co, Ltd, Shenyang Institute of Automation of Chinese Academy of Sciences, China Academy of Information and Communications Technology (CAICT), Intel Corporation, ARM, and iSoftStone.[38] Its goals are to strengthen the edge computing industry by: (1) promoting open cooperation (which can include development of unified terminologies and architectures); (2) nurturing the industry's best practices; and (3) advancing sound and sustainable development of edge computing.[39]

Edge computing will become increasingly important as the next step beyond fog computing. This paradigm will be a key part of the new 5G Mobile Communication System that is under development.[22] The 5G (or fifth generation) mobile network system will provide faster service with shorter latency and lower power consumption than is possible with the currently used 4G (or fourth generation) system.[40] Edge computing is expected to be a key enabler of processes where a rapid response to sensor input is necessary, such as wireless health monitoring, virtual reality, self-driving cars, robotics, drones, and finding lost children. As the amount of data generated by the IoT increases, including diabetes-related data, the need for distributed computing based on fog computing and edge computing architectures will progressively increase.

Abbreviations

CAICT, China Academy of Information and Communications Technology; IoT, Internet of Things.

Acknowledgments

Jeff Reynolds provided helpful advice about the technology discussed in the article. Annamarie Sucher provided excellent editorial assistance.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: The author is a consultant for Ascensia, Insulet, Lifecare, Onduo, and Voluntis.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

References

1. Regalado A. Who coined “cloud computing”? 2011. Available at: https://www.technologyreview.com/s/425970/who-coined-cloud-computing/. Accessed March 3, 2017.
2. Cisco. Cisco global cloud index: forecast and methodology, 2015-2020. Available at: http://www.cisco.com/c/dam/en/us/solutions/collateral/service-provider/global-cloud-index-gci/white-paper-c11-738085.pdf. Accessed March 3, 2017.
3. Cisco. Fog computing and the Internet of things: extend the cloud to where the things are. Available at: https://www.cisco.com/c/dam/en_us/solutions/trends/iot/docs/computing-overview.pdf. Accessed March 3, 2017.
4. Kempe S. The future of cloud computing: fog computing and the Internet of things. 2015. Available at: http://www.dataversity.net/the-future-of-cloud-computing-fog-computing-and-the-internet-of-things/. Accessed March 3, 2017.
5. Luan TH, Gao L, Li Z, Xiang Y, We G, Sun L. Fog computing: focusing on mobile users at the edge. 2016. Available at: https://arxiv.org/pdf/1502.01815.pdf. Accessed March 3, 2017.
6. Kempe S. The future of cloud computing: fog computing and the Internet of things. 2014. Available at: http://www.dataversity.net/the-future-of-cloud-computing-fog-computing-and-the-internet-of-things/. Accessed March 3, 2017.
7. Yi S, Hao Z, Qin Z, Li Q. Fog computing: platform and applications. In: *2015 Third IEEE Workshop on Hot Topics in Web Systems and Technologies*. Available at: http://www.cs.wm.edu/~liqun/paper/hotweb15.pdf. Accessed March 3, 2017.
8. ACM. Fog computing and its role in the internet of things. ACM 978-1-4503-1519-7/12/08. 2012. Available at: http://conferences.sigcomm.org/sigcomm/2012/paper/mcc/p13.pdf. Accessed March 3, 2017.
9. Garcia Lopez P, Montresor A, Epema D, et al. Edge-centric computing: vision and challenges. *ACM SIGCOMM Computer Communication Review*. 2015;45(5):37-42. Available at: http://www.sigcomm.org/sites/default/files/ccr/papers/2015/October/0000000-0000005.pdf. Accessed March 3, 2017.
10. Skala K, Davidovic D, Afgan E, Sovic I, Sojat A. Scalable distributed computing hierarchy: cloud, fog and dew computing. *OJCC*. 2015;2(1):16-24. Available at: https://www.ronpub.com/OJCC_2015v2i1n03_Skala.pdf. Accessed March 3, 2017.
11. Greenfield D. Fog computing vs. edge computing: what’s the difference? 2016. Available at: http://www.automationworld.com/fog-computing-vs-edge-computing-whats-difference. Accessed March 3, 2017.
12. Rouse M, Shea S, Wigmore I. Fog computing (fog networking, fogging). 2016. Available at: http://internetofthingsagenda.techtarget.com/definition/fog-computing-fogging. Accessed March 3, 2017.
13. Munir A, Kansakar P, Khan SU. IFCIoT: integrated fog cloud IoT architectural paradigm for future Internet of things. arXiv:1701.08474v1 [cs.DC]. 2017. Available at: https://arxiv.org/pdf/1701.08474.pdf. Accessed March 3, 2017.
14. Marr B. What is fog computing? *And why it matters in our big data and IoT world*. 2016. Available at: http://www.forbes.com/sites/bernardmarr/2016/10/14/what-is-fog-computing-and-why-it-matters-in-our-big-data-and-iot-world/#51ab6ef04971. Accessed March 3, 2017.
15. Pierson RM. How does fog computing differ from edge computing? 2016. Available at: http://readwrite.com/2016/08/05/fog-computing-different-edge-computing-pl1/. Accessed March 3, 2017.
16. Tracy P. Fog computing rolls over critical IoT data as cloud steps aside. 2016. Available at: http://industrialiot5g.com/20160826/5g/fog-computing-tag31-tag99. Accessed March 3, 2017.
17. Augur H. Is fog computing the future of the cloud? 2015. Available at: http://dataconomy.com/2016/03/fog-computing-future-cloud/. Accessed March 3, 2017.
18. Blue Coat Systems, Inc. *Australia Data Privacy Laws*. Available at: https://www.bluecoat.com/resources/cloud-governance-data-residency-sovereignty/australia-data-privacy-laws. Accessed March 3, 2017.
19. Magalhaes RM, Magalhaes ML. Cloud data jurisdiction: the provider, the consumer and data sovereignty. 2015. Available at: http://www.cloudcomputingadmin.com/articles-tutorials/compliance-regulations/cloud-data-jurisdiction-provider-consumer-and-data-sovereignty.html. Accessed March 3, 2017.
20. Barker I. What you need to know about fog computing. 2016. Available at: http://betanews.com/2016/11/17/fog-computing-breakdown-2/. Accessed March 3, 2017.
21. Ahmed A, Ahmed E. A survey on mobile edge computing. In: *2016 10th International Conference on Intelligent Systems and Control (ISCO)*. Coimbatore; 2016:1-8. doi:10.1109/ISCO.2016.7727082.
22. Shi W, Cao J, Zhang Q, Li Y, Xu L. Edge computing: vision and challenges. *IEEE Internet Things J*. 2016;3(5):637-646.
23. Bluetooth. Medical & health: Bluetooth is changing the face of healthcare. Available at: E.bluetooth.com/

what-is-bluetooth-technology/where-to-find-it/medical-health. Accessed March 3, 2017.
24. Comstock J. CES 2016: running list of health and wellness devices. 2016. Available at: http://www.mobihealthnews.com/content/ces-2016-running-list-health-and-wellness-devices. Accessed March 3, 2017.
25. Ng HS, Sim ML, Tan CM, Wong CC. Wireless technologies for telemedicine. *BT Technol J*. 2006;24(2):130-137.
26. Thiel S, Mitchell J, Williams J. Coordination or collision? The intersection of diabetes care, cybersecurity, and cloud-based computing. *J Diabetes Sci Technol*. 2017;11(2):195–197.
27. Yang Z, Zhou Q, Lei L, Zheng K, Xiang W. An IoT-cloud based wearable ECG monitoring system for smart healthcare. *J Med Syst*. 2016;40(12):286.
28. Jacobs PG, Resalat N, El Youssef J, et al. Incorporating an exercise detection, grading, and hormone dosing algorithm into the artificial pancreas using accelerometry and heart rate. *J Diabetes Sci Technol*. 2015;9(6):1175-1184.
29. Blauw H, Keith-Hynes P, Koops R, DeVries JH. A review of safety and design requirements of the artificial pancreas. *Ann Biomed Eng*. 2016;44(11):3158-3172.
30. Dargaville PA, Sadeghi Fathabadi O, Plottier GK, et al. Development and preclinical testing of an adaptive algorithm for automated control of inspired oxygen in the preterm infant. *Arch Dis Child Fetal Neonatal Ed*. 2017;102(1):F31-F36.
31. XenonHealth. *Sedasys Machines: Are They the Future of Anesthesia*? 2016. Available at: https://xenonhealth.com/sedasys-machines-future-anesthesia/. Accessed March 3, 2017.
32. Zhigalov A, Kaplan A, Palva JM. Modulation of critical brain dynamics using closed-loop neurofeedback stimulation. *Clin Neurophysiol*. 2016;127(8):2882-2889.
33. Klonoff DC. Smart sensors for maintaining physiologic homeostasis. *J Diabetes Sci Technol*. 20115(3):470-475.
34. BI Intelligence. Edge computing in the IoT: forecasts, key benefits, and top industries adopting an analytics model that improves processing and cuts costs. 2016. Available at: http://www.businessinsider.com/edge-computing-in-the-iot-forecasts-key-benefits-and-top-industries-adopting-an-analytics-model-that-improves-processing-and-cuts-costs-2016-7. Accessed March 3, 2017.
35. MacGillivray C, Turner V, Clarke RY, et al. *IDC FutureScape: Worldwide Internet of Things 2016 Predictions*. Doc # 259856. 2015. Available at: https://www.idc.com/research/viewtoc.jsp?containerId=259856. Accessed March 3, 2017.
36. Bresnick J. How fog computing may power the healthcare Internet of things. Available at: http://healthitanalytics.com/features/how-fog-computing-may-power-the-healthcare-internet-of-things. Accessed March 3, 2017.
37. Open Fog Consortium. Available at: https://www.openfogconsortium.org/. Accessed March 3, 2017.
38. Edge Computing Consortium. Edge computing consortium is established to deepen digital transformation. 2016. Available at: http://www.prnewswire.com/news-releases/edge-computing-consortium-is-established-to-deepen-digital-transformation-300370326.html#continue-jump. Accessed March 3, 2017.
39. Edge Computing Consortium. White paper of edge computing consortium. Available at: https://www.iotaustralia.org.au/wp-content/uploads/2017/01/White-Paper-of-Edge-Computing-Consortium.pdf. Accessed March 3, 2017.
40. Gupta L, Jain R, Chan HA. Mobile edge computing—an important ingredient of 5G networks. 2016. Available at: http://sdn.ieee.org/newsletter/march-2016/mobile-edge-computing-an-important-ingredient-of-5g-networks. Accessed March 3, 2017.