*Spotlight*

# Internet of Things Perspectives

## Smart IoT: IoT as a Human Agent, Extension, and Complement

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Everyone reading this will be aware of the explosive growth of sensors and devices that communicate—that is, the Internet of Things (IoT). The IoT now covers virtually every aspect of human interest and existence. These IoTs are within our bodies, on our bodies, observing our activities, monitoring and reporting on our appliances, houses, and buildings, our cars and environment, and many facets of our cities, planet, oceans, and space. They are starting to play a role in our health, fitness and wellbeing, our comfort and entertainment, our financial activities, and many other facets of life.

The pace of development for new types of sensors and devices is quite rapid already. Data that the IoT creates is accessible through the Internet, so accessing and delivering it isn't a big challenge. However, since 2008, we've lost the capacity to store all the data we generate. Therefore, we face one challenge in particular: Do we have the capacity to analyze all this data in a timely manner to determine if it's of interest or value to anyone for a specific purpose? According to one estimate, only 0.5 percent of all data gets analyzed today, and that figure is certain to go down.

There are some near-term interoperability and middleware challenges to achieving interoperability at the device, networking, and data-exchange levels. These issues can be addressed based on our past experiences with similar challenges. For example, Samsung and Google's collaboration on a low-power wireless network called Thread uses Bluetooth Smart to connect one device to another. Samsung, Dell, and Intel's efforts on the Open Interconnect Consortium are working to connect any device with another, regardless of the operating system, connection provider, or form factor.

However, the challenge of interoperating and integrating data and information is the more important and demanding task. To this end, one effort, called Semantic Gateway as Service (SGS),[1] allows for translation between a variety of IoT messaging protocols in current use, such as the Extensible Messaging and Presence Protocol (XMPP), the Constrained Application Protocol (CoAP), and MQTT. Another important interoperability capability is provided by the World Wide Web Consortium (W3C)'s Semantic Sensor Network (SSN) ontology and annotation framework.[2] It's useful to describe any sensor or device and its data in a standard form and support semantic annotations of sensor data, making that data more meaningful. In essence, this provides semantic interoperability between messages carrying IoT data. The W3C has paired up with the Open Geospatial Consortium to make an international standard with SSN as the primary input.

An even bigger challenge will be for those who are recipients of all this data—both humans and machines, including software agents. How will all this data find its way to those who can consume and benefit from it in a timely manner? How can we prevent massive data and information overload?

Today, everyone is looking for everything to be smart. We have all heard of the smart watch, smart home, smart building, smart car, smart city, smart grid, and smart nation. IoT technology will play a crucial role for all of these. After all, as Tim O'Reilly notes, the IoT is more about *human augmentation*,[3] or *computing for human experience*,[4] the latter of which I've used before.

To the IoT data, I would add all the data, collective intelligence (as in Wikipedia), and knowledge we find on the Web, as well as relevant explicit or implicit social interactions, including those enabled by social media. Collectively, what we have is physical, cyber, and social data (http://wiki.knoesis.org/index.php/PCS), which all play a role in helping humans gain better insights and actionable intelligence.

Humans are ill-equipped to deal with the massive amounts of data coming their way. What we need is highly contextualized and personalized information that's also actionable. I call this *smart data* (http://wiki.knoesis.org/index.php/Smart_Data), a term initially proposed in 2004 but which is increasingly making sense in conveying how all the volume, variety, velocity, and veracity challenges of physical, cyber, and social big data needs to be managed to derive value out of it.

By marrying smart data with the IoT, we will get the smart IoT network, which will take up a role as a human agent, or become a human extension and human complement. Consider the human brain's ability to simultaneously and in real time consume data of different modalities, such as text, images, speech, and video, then process it using the human's knowledge, experiences, and preferences to achieve what we call human cognition and perception.

As our ability to create smart data advances, we will similarly see more abilities on the part of machines to

intelligently filter just the data that's needed to meet its human master's needs, assimilate all forms of contextually relevant data, personalize it by factoring in a user's preferences and needs, and present the results at a level of abstraction that's ready for a human to act on.

Initially, we will see more intelligence in the computing environment that will process IoT data, but eventually we will see IoT networks themselves becoming smart or intelligent, complementing some of the exciting advances we see now in robotics.

So, here is the take away: the IoT and artificial intelligence, especially semantic, cognitive, and perceptual computing, will come together to create a smart IoT that will act as a human agent, human extension, and human complement. For more on this topic, see the video at **http://youtu.be/skX7DjB2lyg.**

## References

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4. A. Sheth, "Computing for Human Experience: Semantics-Empowered Sensors, Services, and Social Computing on the Ubiquitous Web," *IEEE Internet Computing*, vol. 14, no. 1, 2010; doi:10.1109/MIC.2010.4

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