Kim Fowler

Sensor Survey: Part 2
Sensors and Sensor Networks in Five Years

Part 1 of this column, in the February 2009 issue of this magazine, described the current state of sensors and sensor networks according to the responses returned in the sensor survey that I sent out [1]. This column will show where the survey respondents think sensors and sensor networks are going within the next 5 years. Some background of the survey is given here from Part 1.

During the summer of 2008, I created a sensor survey and sent it to the IEEE I&M Society, the Sensors and Transducers Journal, and Sensorsmag.com. Conservatively, the appeal to respond to the survey went out to more than 50,000 people. My goal was to better understand how sensors are used and how they might be used within 5 years time. The survey was taken by 468 people; of those, 21 had not had any meaningful involvement with sensors within the past 5 years, and this group did not answer any questions regarding sensors. The remaining 447 people, who were involved in developing or using sensors, took the survey; of that group, 168 responded to more questions about the sensors that they currently use.

SurveyMonkey.com hosted the survey. The survey did not collect any personal information about respondents to maintain their anonymity. When I developed the survey, I did not restrict it to one response per computer, in the event that several people used the same computer to respond to the survey. I also did not force answers to each question to avoid frustrating respondents and possibly causing them to exit the survey early; I would rather have some answers than none.

I refined the survey through four successive pilot surveys sent out to very small groups of trusted colleagues between June and August 2008. Each time I sent the pilot survey to different colleagues to try to reduce the bias. The final survey was completed and became active for inputs in late August when the appeals were sent to fill in the survey.

Who is doing what?

In Part 1, respondents answered 4 questions that gave some background into their involvement with sensors. The results are summarized here. The vast majority of people answering the survey were in either academia (42%) or industry (47%). Respondents primarily did both research (academic 41% and industrial 11%) and design and development (25%). The largest field of application was basic research (41%), followed by petroleum/natural gas/chemical processing (15%), automotive (13%), industrial machinery and vehicles (13%), medicine and healthcare (13%), and aerospace (12%). Part 1 covered the responses from 10 questions that focused on the parameters and characteristics of sensors and sensor networks. Each respondent was asked to focus on a single, primary sensor for which they had familiarity. The survey then directed the respondent in reference to that sensor.

Four sets of instructions/questions from the survey addressed the "future, predicted state of sensors and sensor networks". The first in these sets of instructions asked respondents to rate the importance of eight different parameters. The results follow in Table 1 and Figure 1 (the instruction is repeated at the top of Table 1). Clearly, most people want dependable, low-power, and long-lived sensors. Following closely on these three characteristics, people would like low cost, small size, and survival in environmental extremes.

The second instruction (the specific instruction is repeated at the top of Table 2) was to predict how specific parameters for sensors will change in the next five years. The parameters are speed of operation, accuracy/resolution, reduction in power consumption, and decrease in size of the sensor. The results follow in Table 2 and Figure 2.

Table 1. Future of Sensors

Rate each of these characteristics for sensors in the field of application that you chose in question 6.

	very important	important	low importance	not important	Response Count
Dependability	208	128	20	4	
Cost	120	179	57	10	
Power consumption	121	124	96	21	
Size, volume, mass	96	195	67	6	
Environmental extremes	123	146	76	14	
Ease of diagnostics	103	184	64	11	
Security of data	80	121	120	42	
Installed longevity	150	162	41	7	
				Comments	
				answered question	
				skipped question	

Table 1. Ratings for 8 different characteristics for sensors in the field of application chosen by respondents. (© 2008 by Kim Fowler. Used with permission. All rights reserved.)

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Fig. 1 Graphs of the ratings for the eight parameters in Table 1. (© 2008 by Kim Fowler. Used with permission. All rights reserved.)

Table 2. Future of Sensors

Predict how these sensor parameters will change within the next 5 years.

Answer Options	0%	+10%	+20%	+50%	+100%	>+100%	Response Count
Speed	26	91	82	101	30	29	359
Accuracy/ resolution	13	71	115	103	44	21	367
Conservation of power (reduced consumption)	14	39	88	124	56	41	362
% decrease in size	11	55	92	123	47	34	362
						Comments	10
						answered question	**369**
						skipped question	**99**

Table 2 Predict how these sensor parameters will change within the next 5 years. (© 2008 by Kim Fowler. Used with permission. All rights reserved.)

Table 3. Future of Sensors

Predict how sensor networks will change within the next 5 years. (The numbers and types of sensors are per system, as is the total bandwidth.)

Answer Options	0%	+20%	+50%	+100%	+200%	>+200%	Response Count
Numbers of sensors	6	72	85	89	38	43	333
Types of sensors	16	110	92	79	24	15	336
Network bandwidth	13	66	98	98	32	24	331
Secure transmission	17	81	106	83	26	16	329
						Comments	11
						answered question	**338**
						skipped question	**130**

Table 3 Predict how sensor networks will change within the next 5 years. (The numbers and types of sensors are per system, as is the total bandwidth.) (© 2008 by Kim Fowler. Used with permission. All rights reserved.)

A large majority of respondents indicated that the speed of sensor operation will increase between 10% and 50%. Most indicated that accuracy or resolution would increase between 20% and 50%. Even as sensors become faster and more accurate, respondents predicted that power consumption will go down by 50% or more and that sensor size would decrease between 20% and 50%.

The third instruction (the specific instruction is repeated at the top of Table 3) was to predict how specific parameters for networks will change in the next five years. The parameters are the number of sensors per system, the types of sensors per system, the nework bandwidth per system, and secure transmission per system. The results follow in Table 3 and Figure 3.

Most respondents indicate that the number of sensors per system will possibly double in the next five years, while the different types of sensors will not increase as fast – maybe

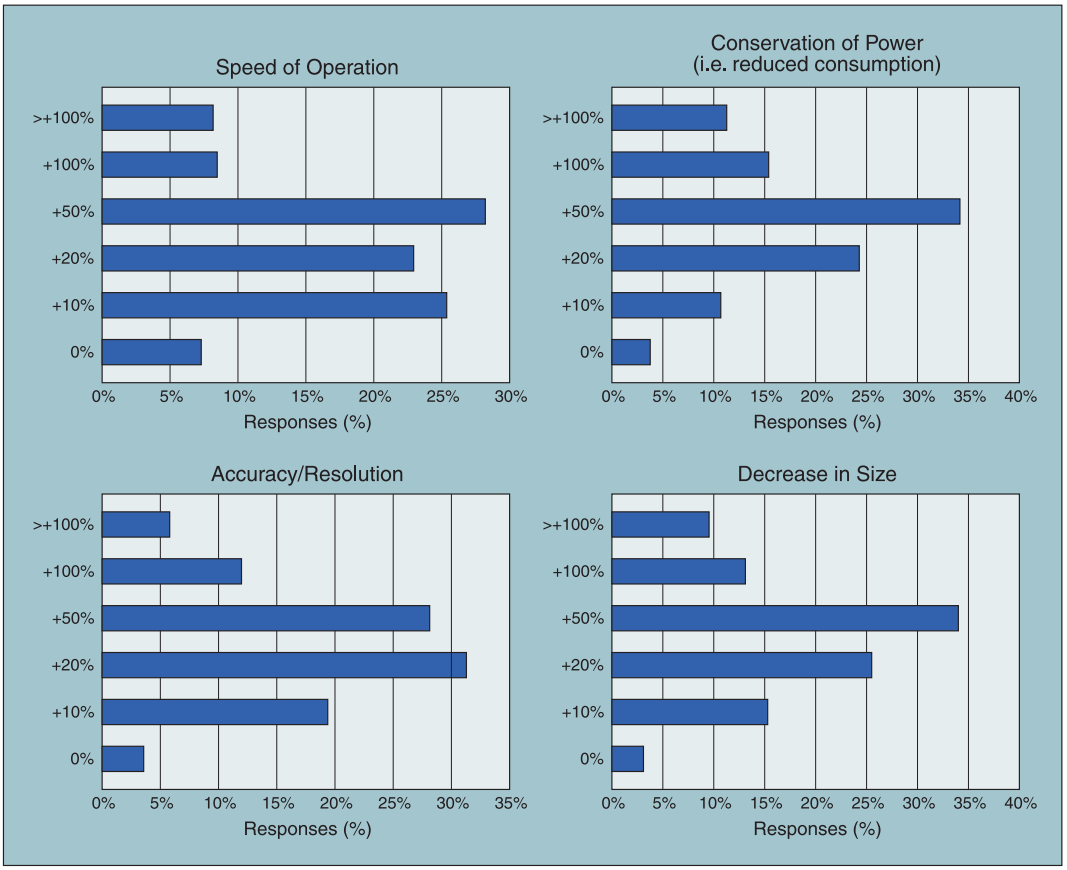

Fig. 2 Separate graphs for how sensor parameters will change within the next 5 years. (© 2008 by Kim Fowler. Used with permission. All rights reserved.)

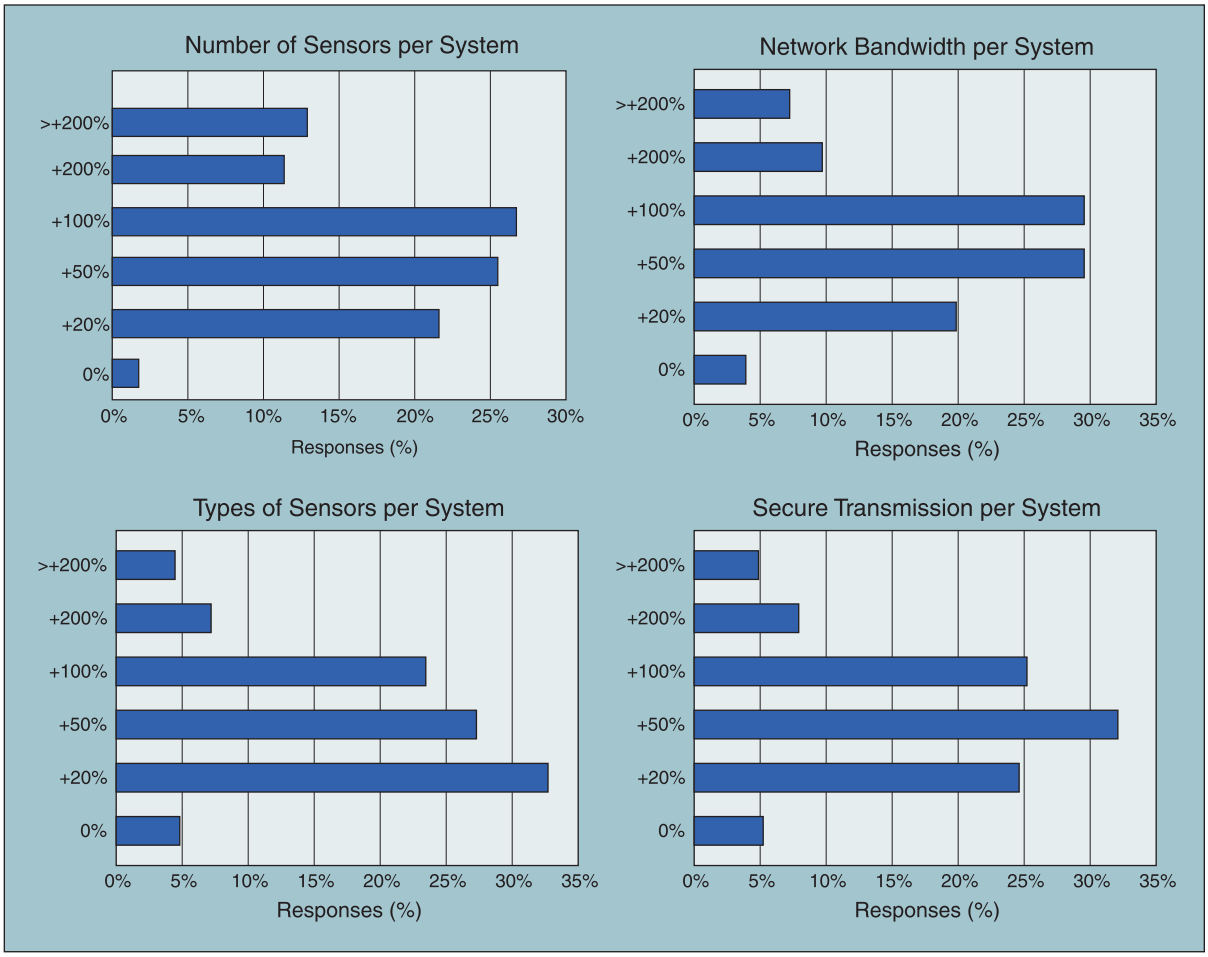

Fig. 3 Separate graphs for how sensor networks will change within the next 5 years. (© 2008 by Kim Fowler. Used with permission. All rights reserved.)

20% to 50%. Many thought that system bandwidth for sensor data will double but that system security would increase about 50%.

The fourth and last question (the question is repeated at the top of Table 4) was to predict how numbers of networks of sensors will increase in the next five years. The types of networks were wired, wireless, and optical. The results follow in Table 4 and Figure 4.

Clearly most people thought that wireless sensor networks will increase rapidly over the next five years — as much as doubling or tripling in number. Most respondents indicate that the number of wired sensor networks will increase in number by 20% to 50% in the next five years; at the same time they indicated that optical sensor networks will have a slightly higher growth rate.

Discussion and Summary

Reviewing the results from Part 2, 330 to 360 people responded to the survey with their predictions for the next five years. Most indicated that the number of sensors per system, the different types of sensors per system, and the number of sensor networks will increase by a factor of 2 or 3 over the next five years. Finally, most respondents clearly indicated that dependable, low-power, and long-lived sensors are important or very important. As mentioned in the summary of Part 1, these results are not from a thoroughly

Table 4. Future of Sensors

What will be the rate of increase in numbers of sensor networks?

Answer Options	0%	+20%	+50%	+100%	+200%	>+200%	Response Count
Wired	28	172	85	32	9	7	333
Wireless	5	36	88	91	66	51	337
Optical	28	110	97	61	20	12	328
						Other (please specify)	9
						answered question	**339**
						skipped question	**129**

Table 4 What will be the rate of increase in numbers of sensor networks over the next 5 years? (© 2008 by Kim Fowler. Used with permission. All rights reserved.)

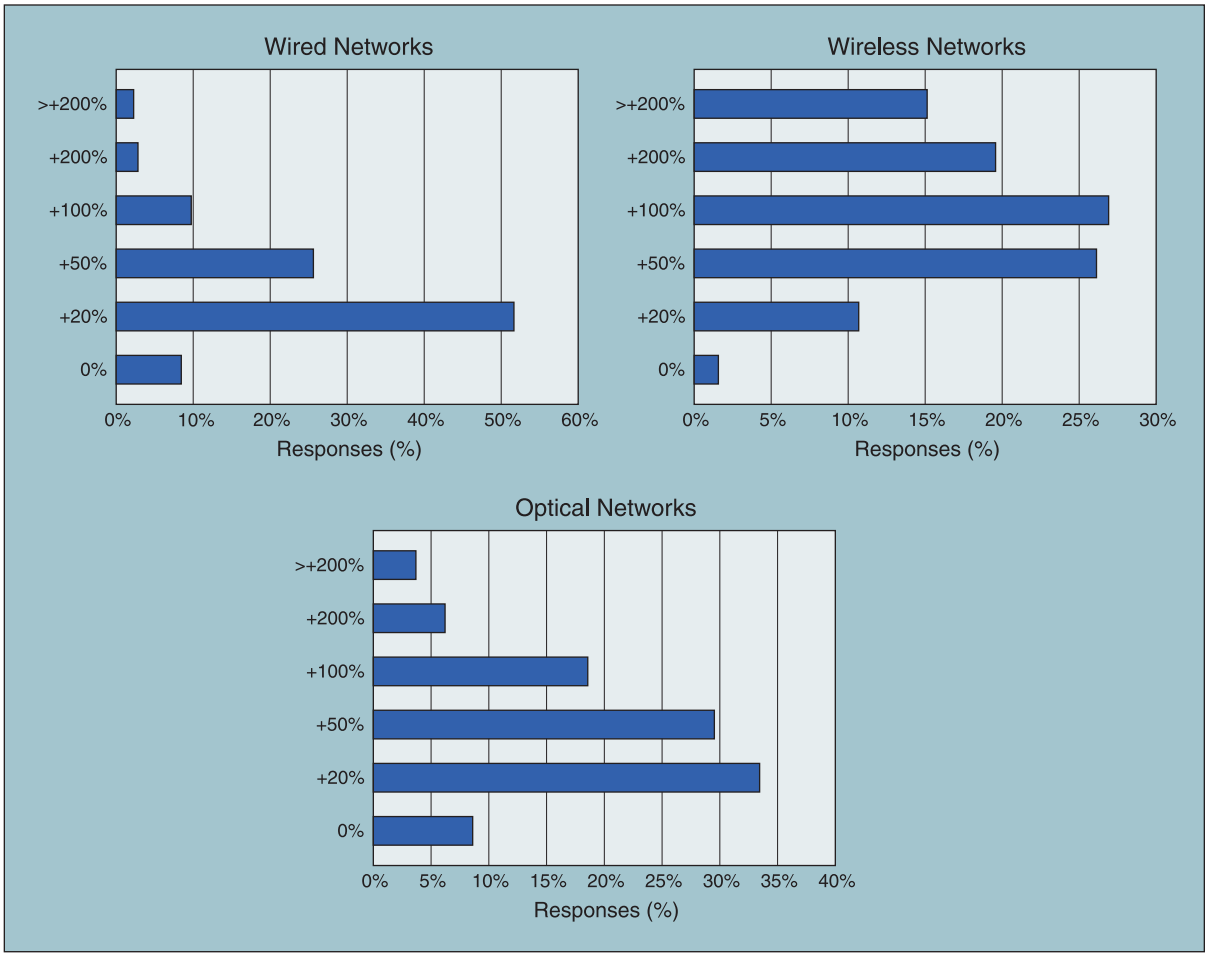

Fig. 4 Separate graphs for the rate of increase in numbers of sensor networks over the next 5 years. (© 2008 by Kim Fowler. Used with permission. All rights reserved.)

scientific and statistically-valid survey. I had no real control over ensuring the consistency of the responses to the questions with respect to the application context; the respondents' perspectives could vary widely as to what they meant by important, minimum or maximum. The survey responses did indicate the future of sensors and sensor networks.

References

[1] K. Fowler, "Sensor Survey: Part 1", IEEE *I&M Magazine*, vol. 12, pp. 39-44, Feb. 2009.

Kim Fowler (kimf@ieee.org) lectures and develops concepts for new products. His web site, www.cool-stream.com, provides notes and advice on designing embedded, real-time products. He is researching the market and seriously considering starting a new sensors business. He is Executive Vice President of the I&M society for 2008 and 2009.